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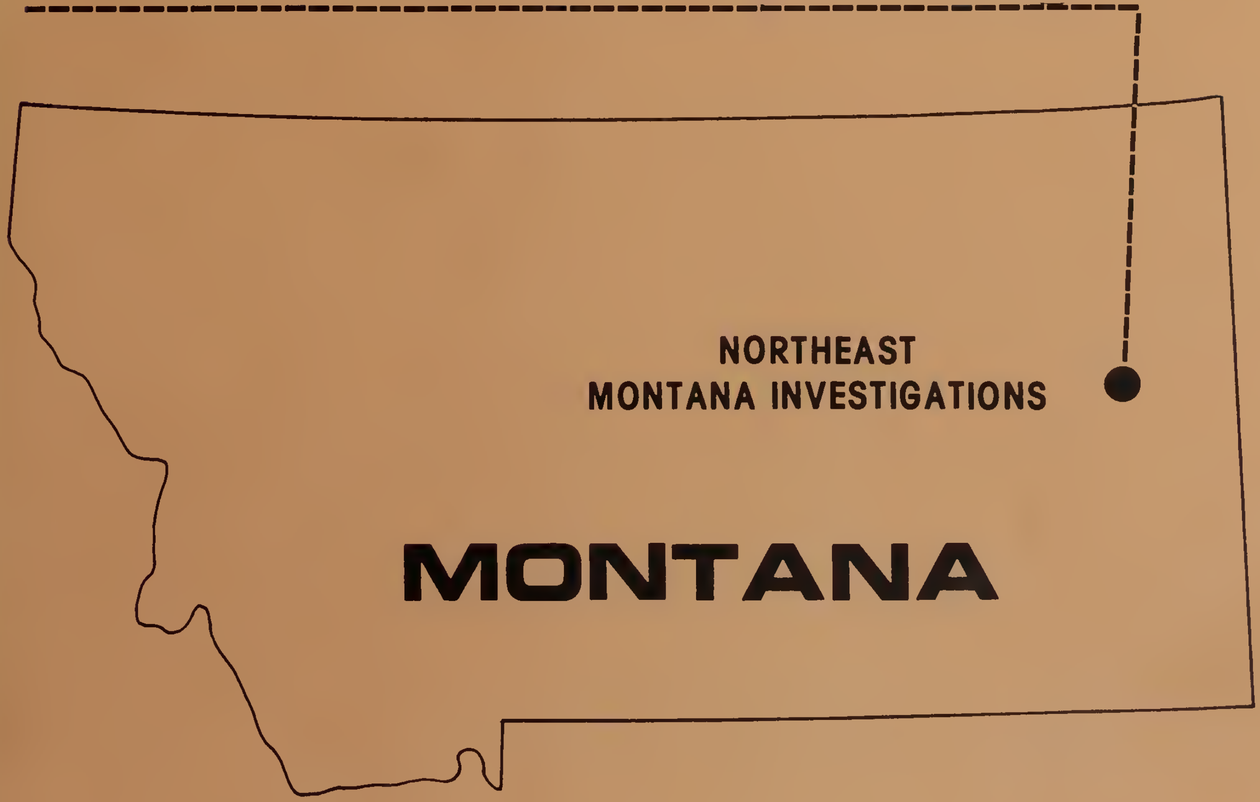

RESOURCE & POTENTIAL RECLAMATION EVALUATION

Northeast Montana Investigations Report
Published July 1983

The Federal Coal Management Program has been designed as an interagency cooperative effort to meet national energy objectives.

Northeast Montana Investigations Report was prepared through the efforts of the U.S. Department of the Interior, principally the Bureau of Land Management and Bureau of Reclamation. The study effort began in 1981 and was concluded in 1983 with the publication of this report.

The areas described in this report have been tentatively determined to be potential Federal coal development areas. The purpose of the report is to provide information on the areas' reclamation potential, should coal development occur. This report will assist managers in making final Federal coal leasing decisions.

Limited copies of the report are available from:

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16. Abstract
The purpose of this investigation was to collect baseline information for establishing reclamation objectives and lease stipulations. The Investigations area, located in northeastern Montana, lies on the border of the glaciated and unglaciated portion of the Great Plains Physiographic Province. The area generally consists of extensive uplands to the southeast of the Missouri-Yellowstone drainage divide and gently rolling topography with isolated buttes to the northwest. Climatic conditions are characterized by cold winters, warm summers, and large variations in seasonal precipitation. Average annual precipitation is about 13 inches; the frost-free season ranges from 110 to 130 days. Bedrock exposed in the area consists predominantly of the Tongue River Member and also the Lebo Shale Member of the Paleocene Fort Union Formation. Miocene to Holocene gravel terraces, Pleistocene glacial deposits, and Holocene alluvial deposits locally mantle the bedrock in the area. Six continuous lignite beds are present in the area, of which four are fairly thick. These beds are the S-, L-, R-, Second Pust Bench, Pust, and Peuse. Soils developing in old or recent alluvium in the area should provide 18 to 36 inches or more of good quality topsoiling material for revegetation. Only 6 to 12 inches of suitable topsoil will be available from the soils forming in residual sandstone, siltstone, shale, or baked rock. Available subsurface materials appear fair to poor in quality. Overburden samples from 9 USBR drill holes were evaluated for use as a supplemental plant medium for revegetation; the physical and chemical charteristics of these materials were highly variable. Twenty-six soil/overburden materials were stratified in the greenhouse as to their comparative revegetation potential.

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1407 Reclamation

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NORTHEAST MONTANA INVESTIGATIONS
DAWSON AND MC CONE COUNTIES
MONTANA

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RESOURCE AND POTENTIAL RECLAMATION EVALUATION
OF
NORTHEAST MONTANA INVESTIGATIONS
DAWSON AND MC CONE COUNTIES, MONTANA

INTRODUCTION

Recent energy shortages have forced our society to seek new domestic energy sources. Attention has focused on the immense quantities of low sulfur coal that lie within the Rocky Mountain and Northern Great Plains regions. It is the responsibility of the Department of the Interior, principally the Bureau of Land Management, to assist in meeting these energy demands and, at the same time, provide sound reclamation guidelines so that the disturbed lands are restored to an acceptable condition.

PURPOSE

The purpose of this report is to provide baseline information for establishing reclamation objectives and lease requirements. Detailed data is given on geology, soil and overburden, and greenhouse investigations. Background information on climate and physiography is also provided.

REPORT OBJECTIVES

1. To provide information for leasing site selection procedures as set forth by the Secretary of the Interior.

2. To provide information needed to implement effective reclamation and rehabilitation programs and for the development of meaningful lease stipulations as required by the mined land reclamation program.

3. To provide information to support State and local regional development and land use planning efforts.

4. To determine the present and potential capability of the soils and overburden to support and maintain vegetation.

5. To provide physical and chemical data on soils and overburden from which realistic stipulations may be prepared for exploration, mining, and reclamation plans.

6. To provide data needed in the preparation of Environmental Impact Statements, Environmental Analysis Records, and to aid in the review of mining and reclamation plans for proposed land disturbing activities in the vicinity of the study area.

AUTHORITY

Federal Land Policy and Management Act of 1976 and Surface Mining Control and Reclamation Act of 1977.

RESPONSIBILITY

BUREAU OF LAND MANAGEMENT

1. Selects the study areas for soil and overburden investigations.

2. Assists in selecting drill hole locations.

3. Acts as Contracting Officer in the coordination, establishment, and execution of work orders.

4. Procures easements and rights-of-way to conduct the studies.

BUREAU OF RECLAMATION

1. Conducts drilling operations to describe core and procure overburden samples.

2. Summarizes the geology of the area.

3. Characterizes and interprets suitability of overburden materials stratigraphically above and below the coal seams.

4. Conducts a land suitability classification of representative sections to determine quality, quantity (depth), and ease of stripping soil and overburden material for reclamation and revegetation.

5. Arranges for greenhouse investigations to determine comparative revegetation potential of selected soil and overburden materials.

6. Coordinates assembly and printing of the final report.

GENERAL DESCRIPTION

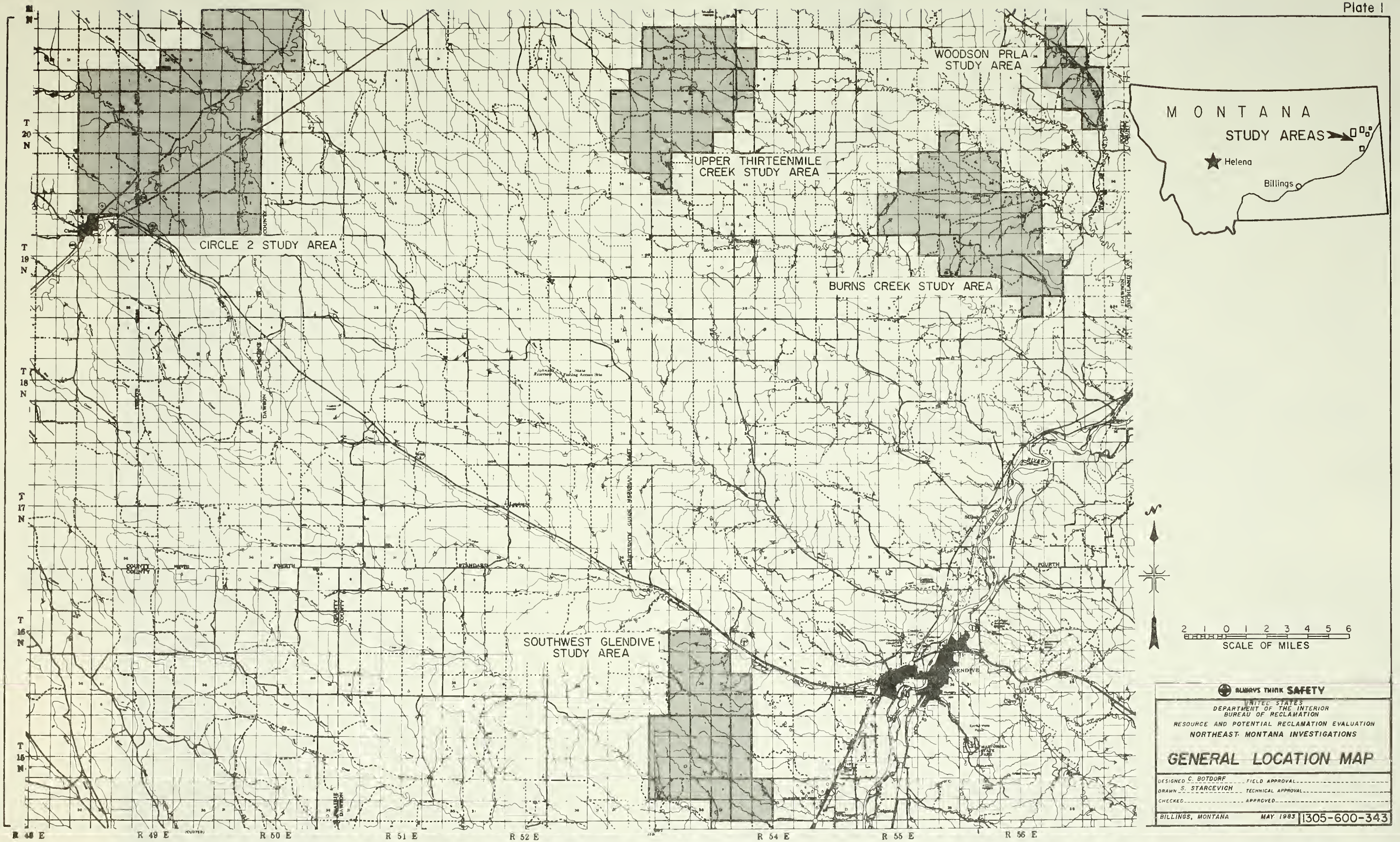
LOCATION

The five study areas included within the Northeast Montana Investigations are located between the Yellowstone and Missouri Rivers in Dawson and McCone Counties. These include the Circle 2, Upper Thirteenmile Creek, Woodson PRLA, Burns Creek, and Southwest Glendive Study Areas. Plate 1 shows the general location of the five study areas.

The Circle 2 Study Area is adjacent and northeast of Circle, Montana. It includes all of T. 20 N., R. 49 E.; section 36 of T. 21 N., R. 48 E.; sections 20 through 29 and 31 through 36 of T. 21 N., R. 49 E.; sections 1 through 3, 10 through 15, 22 through 27, and 34 through 36 of T. 20 N., R. 48 E.; sections 1 through 3 and 12 of T. 19 N., R. 48 E.; and sections 1 through 12 of T. 19 N., R. 49 E., as shown on Plates 2 and 3.

The Upper Thirteenmile Creek Study Area lies 4 miles north of Bloomfield, Montana. It includes the east half of sections 26 and 35, and sections 25 and 36 of T. 21 N., R. 52 E.; sections 28 through 34 of T. 21 N., R. 53 E.; sections 12, 13, and 24 of T. 20 N., R. 52 N.; and sections 1 through 12, 14 through 22, 29, 30, and 32 of T. 20 N., R. 53 N., as shown on Plate 4.

Plate I



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NORTHEAST MONTANA INVESTIGATIONS

GENERAL LOCATION MAP

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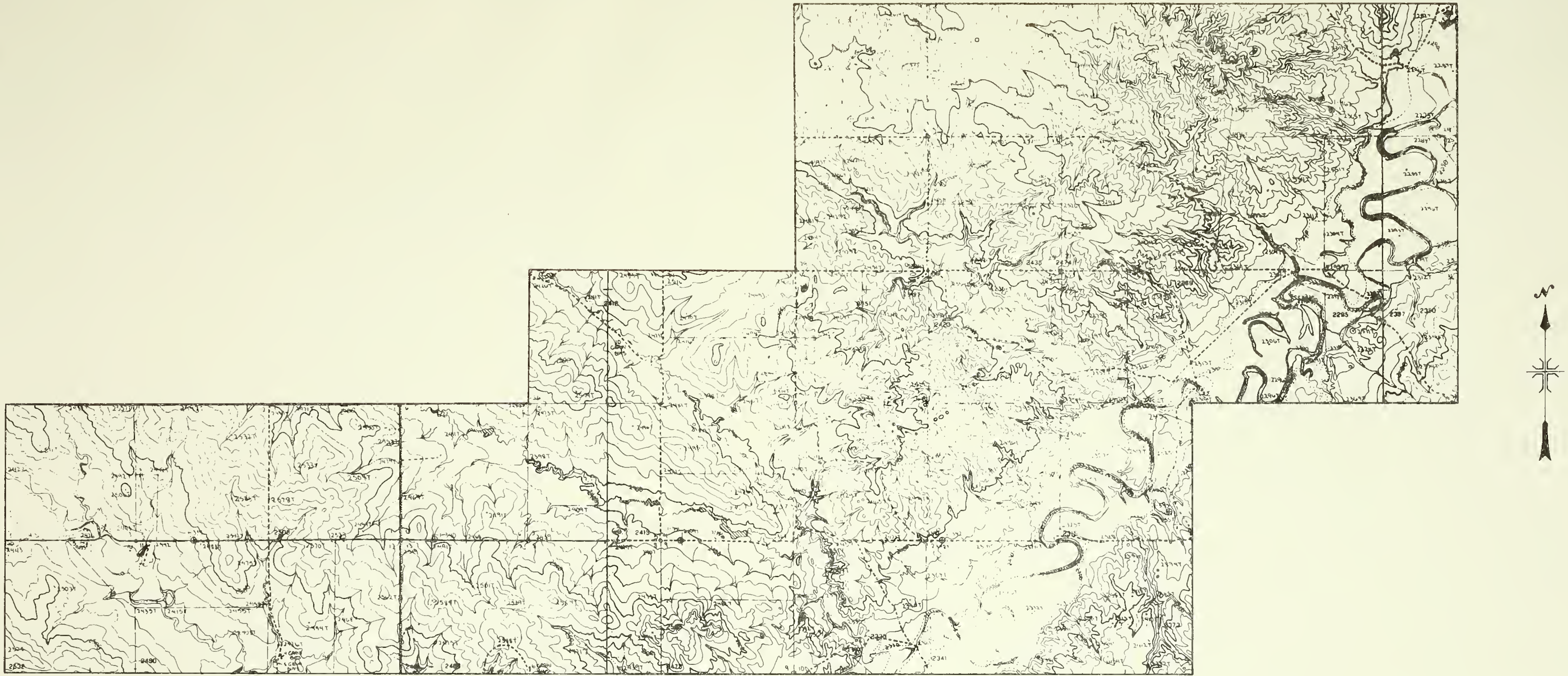
Plate 2



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CIRCLE 2 STUDY AREA

TOPOGRAPHY

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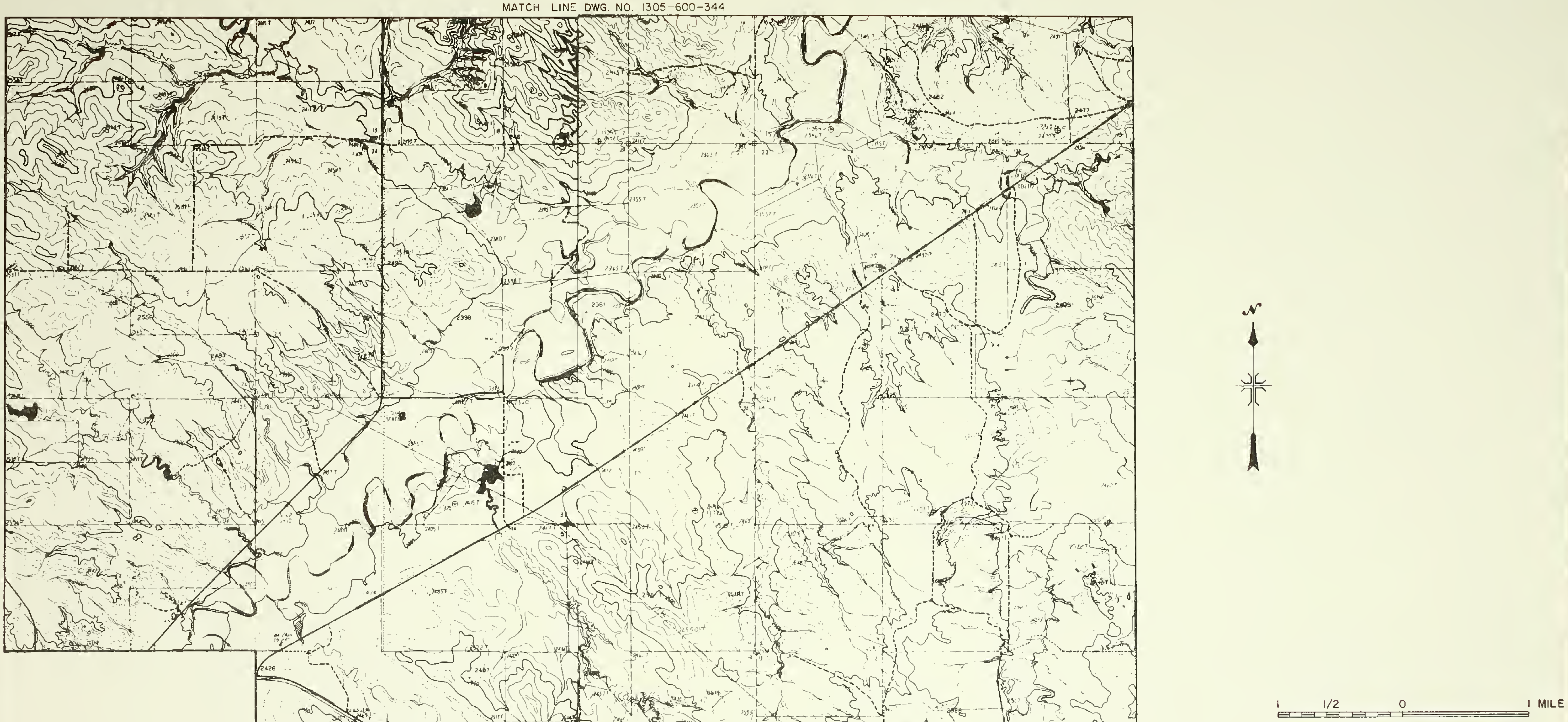
Plate 3



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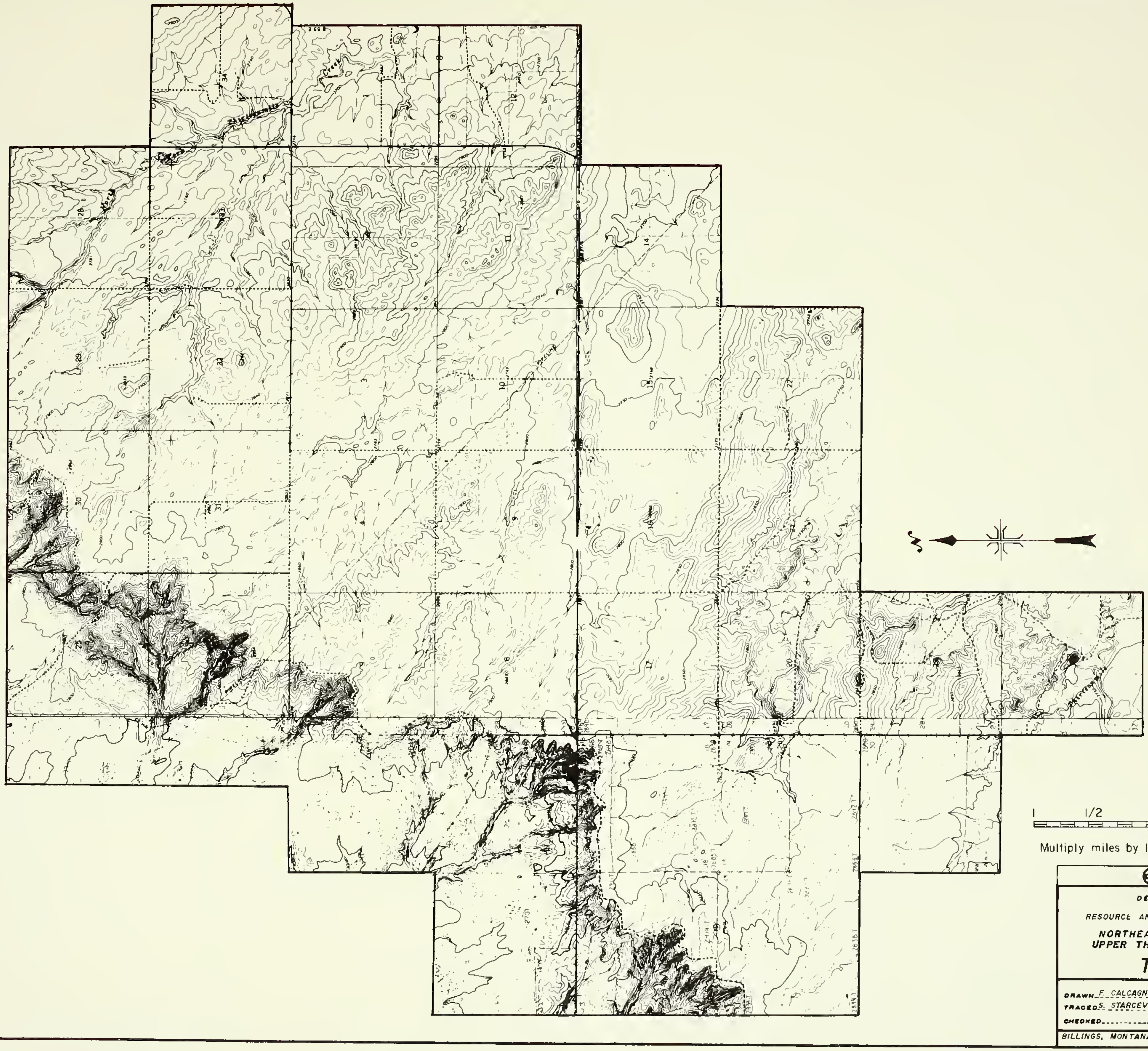

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UPPER THIRTEENMILE CREEK STUDY AREA

TOPOGRAPHY

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The Burns Creek Study Area is located 17 miles north of Glendive, Montana. The study area includes sections 22, 25 through 28, and 32 through 36 of T. 20 N., R. 55 E.; sections 1 through 16, and 22 through 24 of T. 19 N., R. 55 E.; and sections 5 through 8, 17 through 21, 28 through 30, and 32 of T. 19 N., R. 56 E., as shown on Plate 5.

The Woodson PRLA Study Area is the smallest of the five sites, and is located approximately 28 miles northeast of Glendive, Montana. The study area consists of sections 30 through 32 of T. 21 N., R. 56 E., and sections 2 through 4, 10, 11, and 14 of T. 20 N., R. 56 E., as shown on Plate 6.

The fifth study area is the Southwest Glendive Study Area, which is located about 6 miles west of Glendive, Montana. This study area consists of sections 23 through 26, 35, and 36 of T. 16 N., R. 53 E.; sections 30 through 32 of T. 16 N., R. 54 E.; sections 1, 2, 10 through 15, and 22 through 27 of T. 15 N., R. 53 E.; and sections 5 through 8, 17 through 20, and 28 through 33 of T. 15 N., R. 54 E., as shown on Plate 7.

The majority of surface ownership in the five study areas is private, with the remainder consisting of State and Federal lands as shown on Plates 8 through 13. Approximately one half of the coal in the study areas is Federally owned; also shown on Plates 8 through 13.

PRESENT LAND USES

Lands in the Northeast Montana Investigations study areas are presently used for livestock grazing (range) and dryland farming (small grains). Portions of the study areas, particularly the woody draws, provide valuable wildlife habitat.

POSTMINING LAND USES

Postmining land uses are anticipated to be the same as the present uses, livestock grazing (rangeland), dryland farming (cropland), and wildlife habitat.

An opportunity will exist during reclamation to convert some of the present rangeland to cropland. This would involve the reduction of existing steep slopes to a more gently sloping condition conducive to cultivation. This alternative would be at the discretion of the landowner(s) or land management agency (BLM, State) having jurisdiction over the land.

RULES GOVERNING MINING AND RECLAMATION OPERATIONS

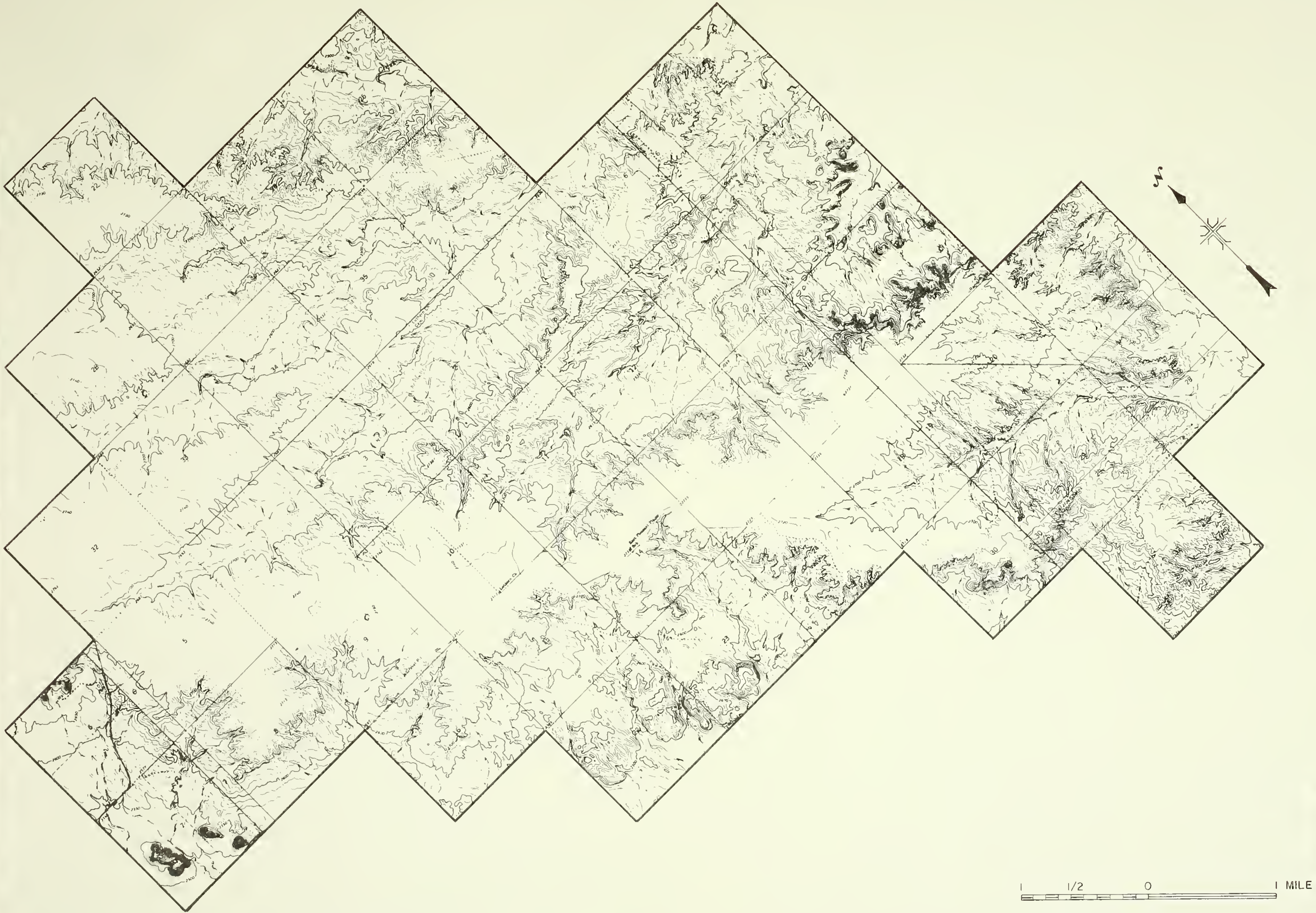
In Montana, coal mine operators must comply with all established rules pursuant to the Montana Strip and Underground Mine Reclamation Act (1973). These rules are presented in Appendix A of the "Montana Permanent Program" for regulating surface and underground mining activities.

The Montana Department of State Lands is the regulatory agency responsible for administering this program.

OBJECTIVE OF RECLAMATION

Montana law presently requires the coal mine operator to restore all disturbed areas "in a timely manner, either to conditions capable of supporting the uses they were capable of supporting before any mining or to conditions capable of supporting approved alternative land uses. Alternative land uses may be approved by the Department of State Lands after consultation with the landowner or land management agency having jurisdiction over the lands . . ." (Rule XVI, 5(c) pursuant to the Montana Strip and Underground Mine Reclamation Act - Montana Permanent Program).

Unless an alternative postmining land use is desired by the landowner(s) and approved by the Montana Department of State Lands, the main objective of reclamation in the five study areas would be to establish a diverse vegetative cover with an interspersion of vegetative types over the reclaimed land capable of supporting livestock and wildlife. The integrity of the visual resource should be maintained.



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BURNS CREEK STUDY AREA

TOPOGRAPHY

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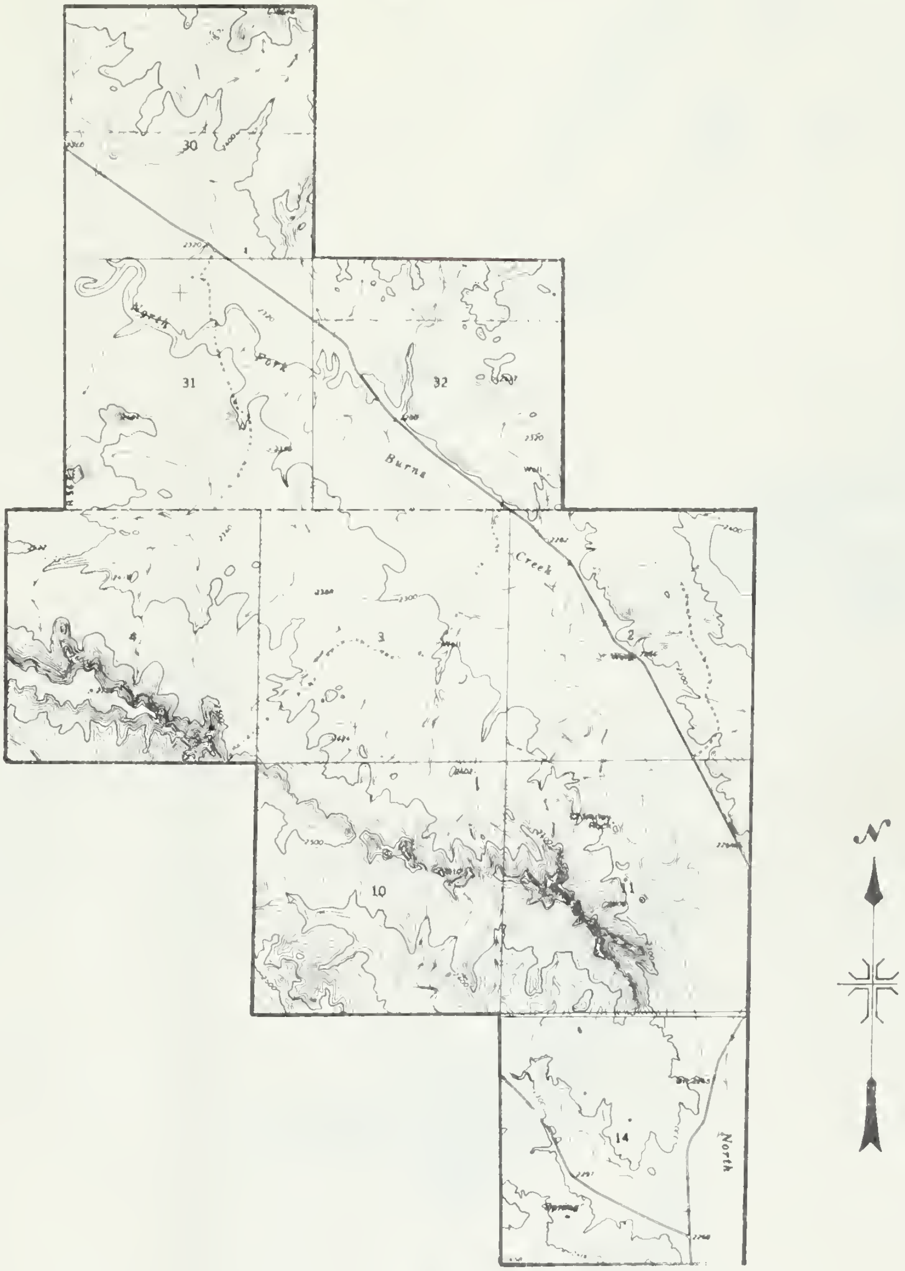

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WOODSON PRLA STUDY AREA

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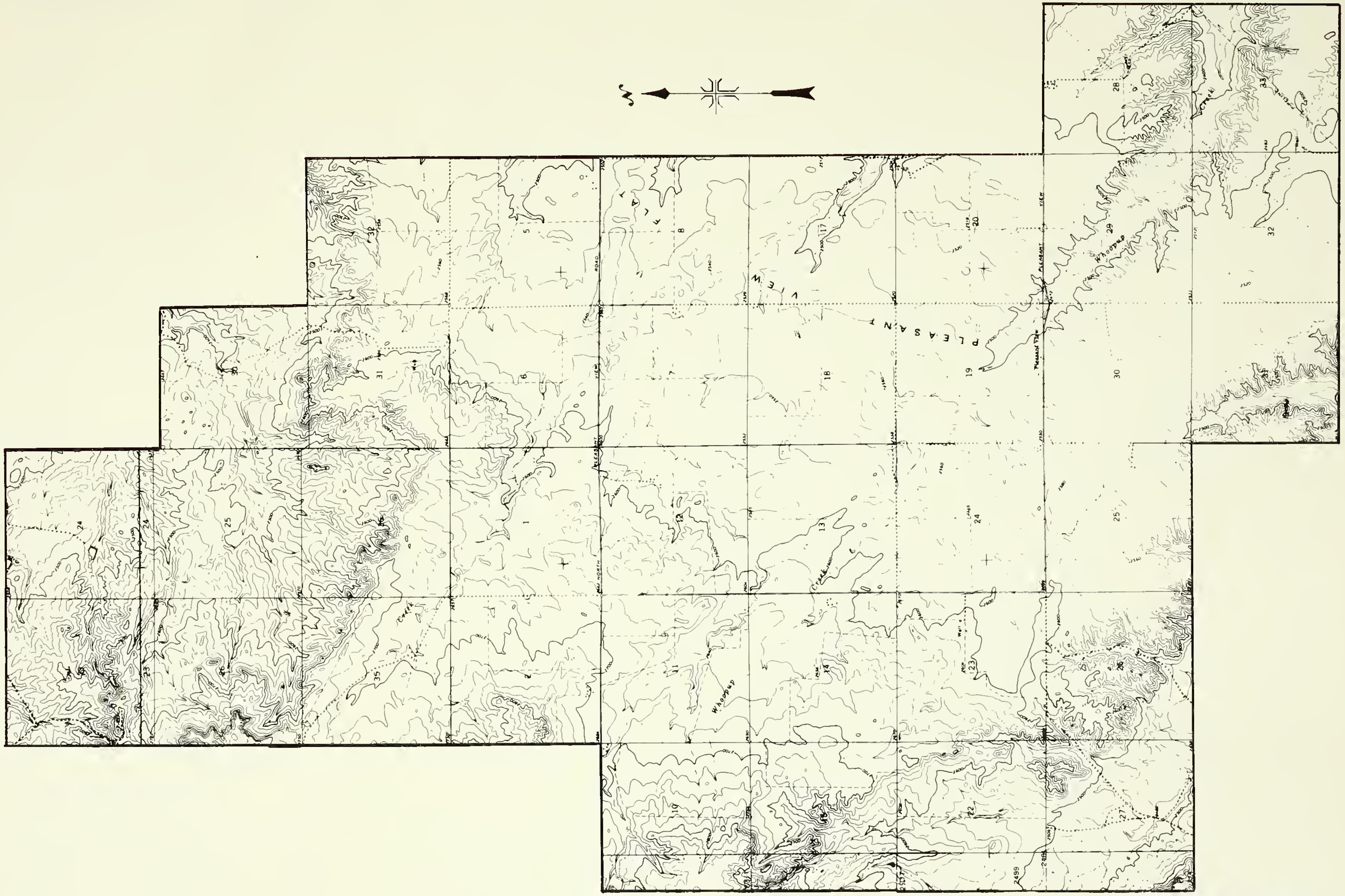
Plate 7



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SOUTHWEST GLENDIVE STUDY AREA

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Plate 8

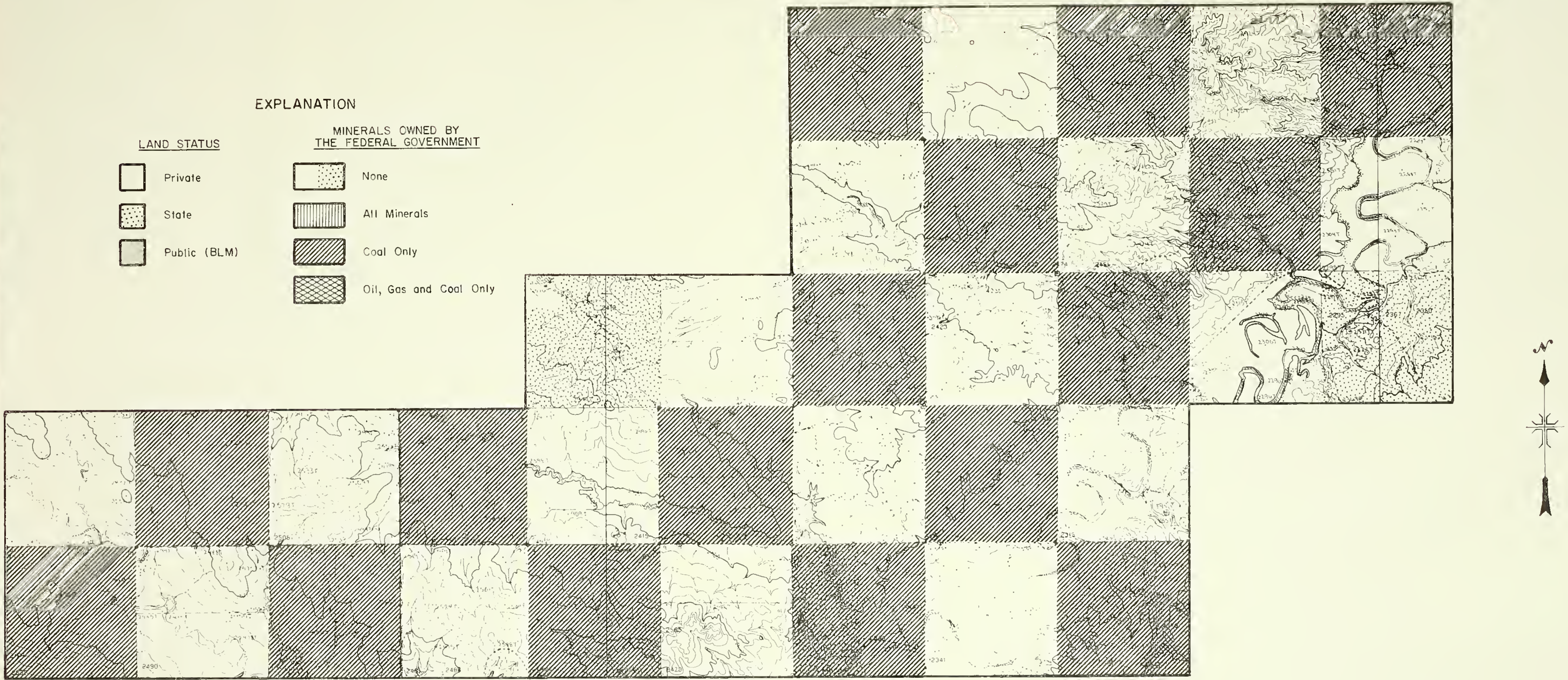
EXPLANATION

LAND STATUS

- ☐ Private
- ▒ State
- ▩ Public (BLM)

MINERALS OWNED BY THE FEDERAL GOVERNMENT

- ☐ None
- ▥ All Minerals
- ▨ Coal Only
- ▩ Oil, Gas and Coal Only



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NORTHEAST MONTANA INVESTIGATIONS
CIRCLE 2 STUDY AREA

LAND AND MINERAL STATUS

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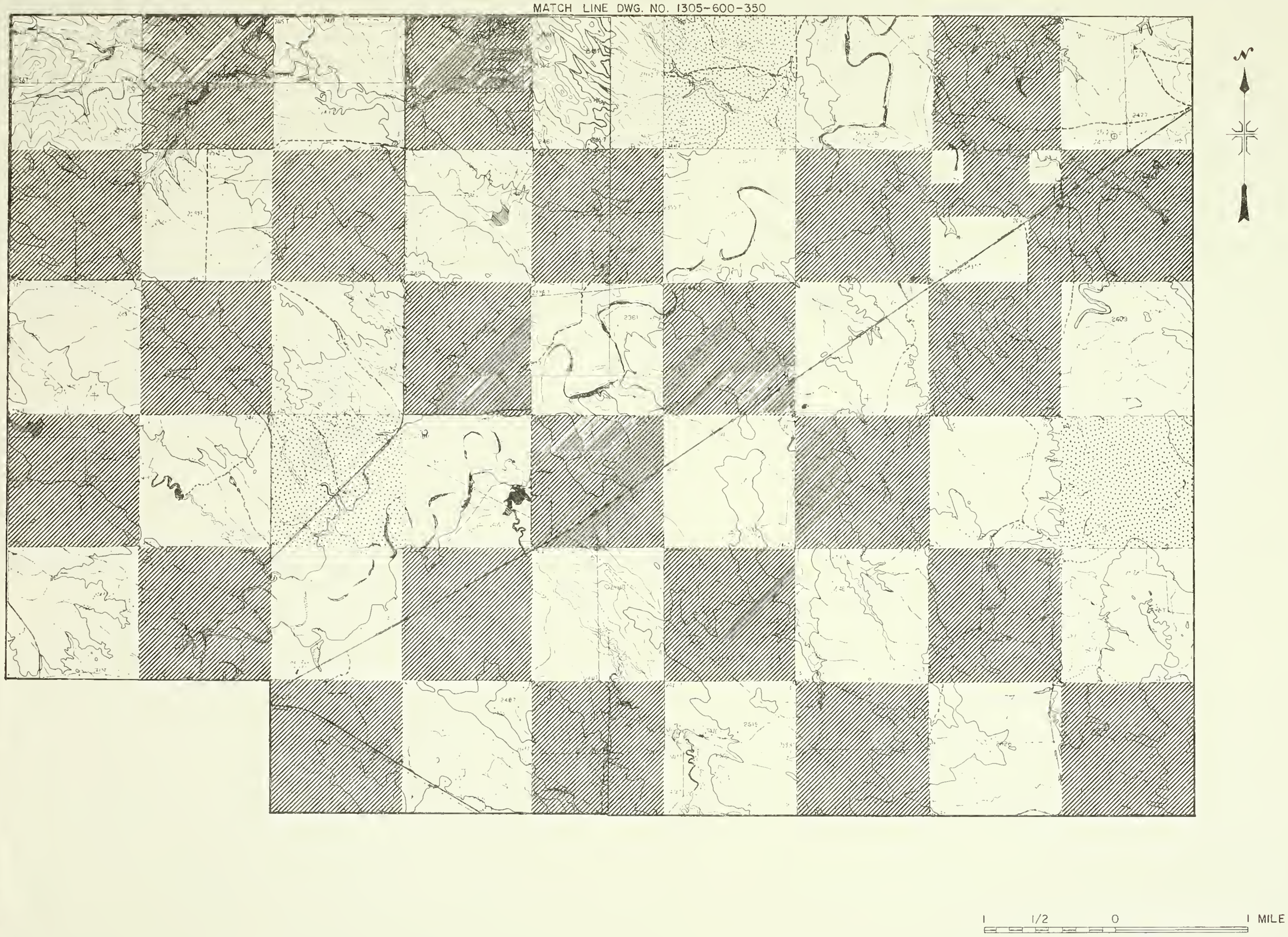
Plate 9



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EXPLANATION

LAND STATUS

☐ Private

▒ State

▢ Public (BLM)

MINERALS OWNED BY THE FEDERAL GOVERNMENT

▒ None

▥ All Minerals

▨ Coal Only

▩ Oil, Gas and Coal Only

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RESOURCE AND POTENTIAL RECLAMATION EVALUATION

NORTHEAST MONTANA INVESTIGATIONS
CIRCLE 2 STUDY AREA

LAND AND MINERAL STATUS

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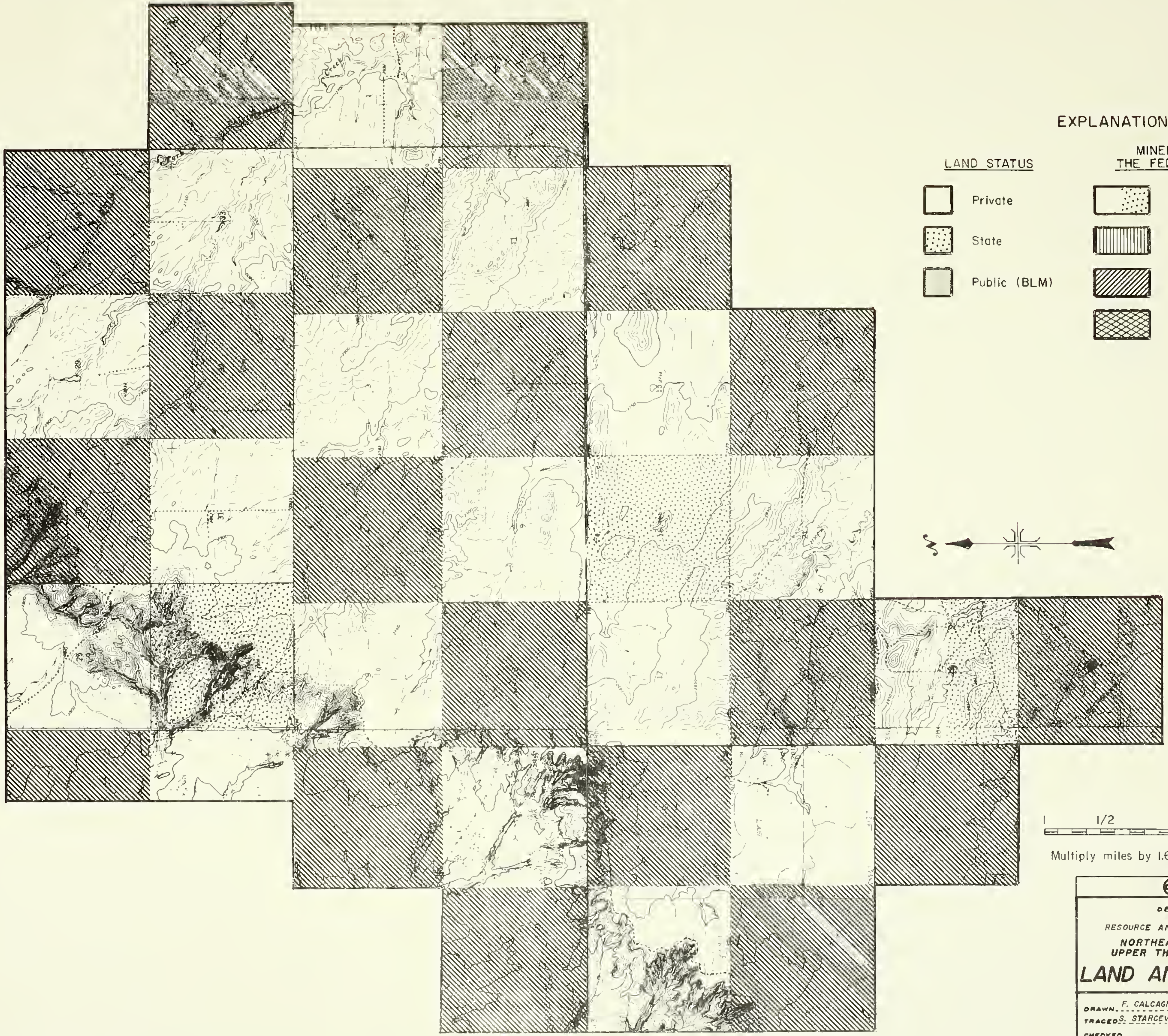
Plate 10



EXPLANATION

LAND STATUS		MINERALS OWNED BY THE FEDERAL GOVERNMENT	
☐	Private	☐	None
⠿	State	▥	All Minerals
☐	Public (BLM)	▨	Coal Only
		▩	Oil, Gas and Coal Only

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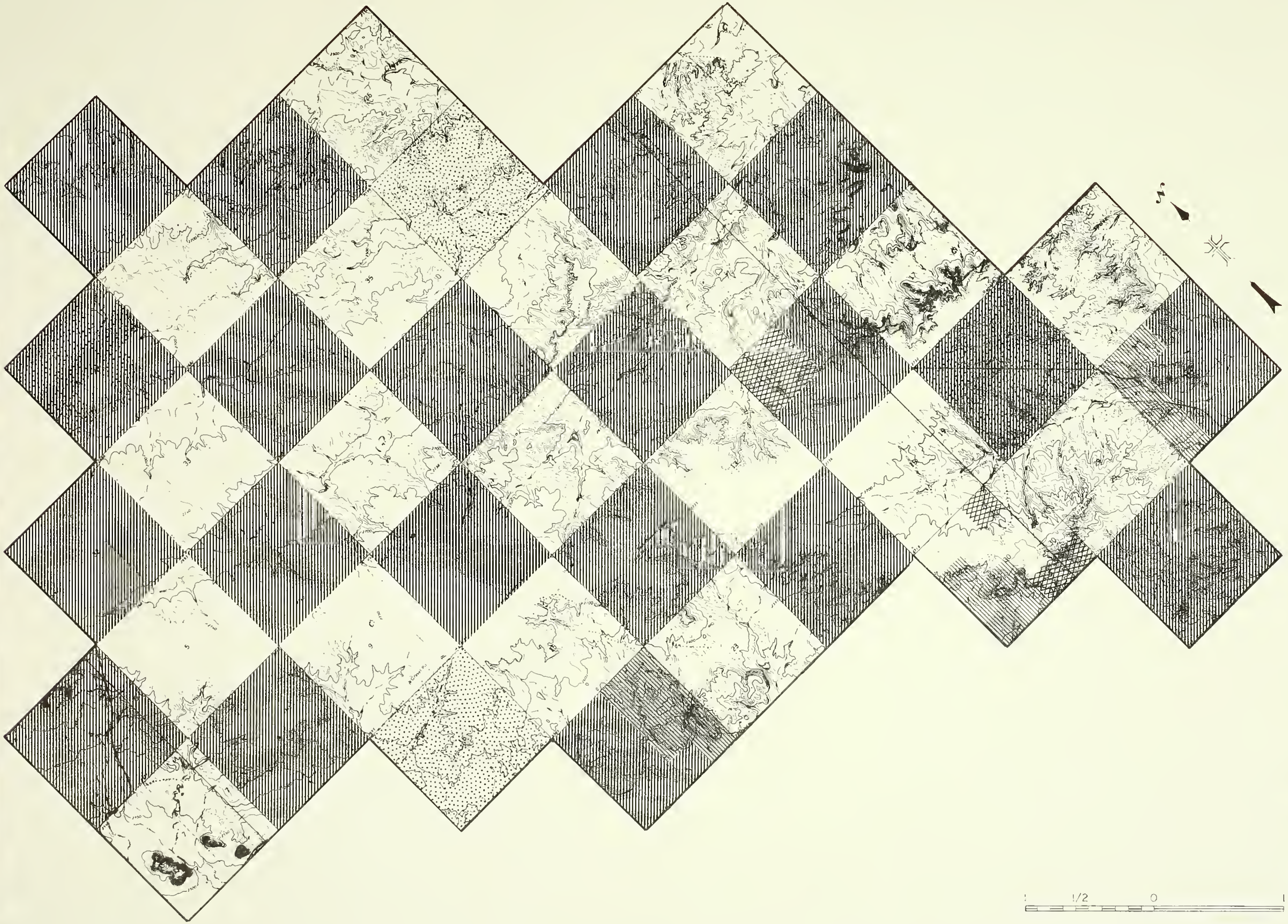
Plate 11



EXPLANATION

LAND STATUS

☐	Private
░	State
☐	Public (BLM)

MINERALS OWNED BY THE FEDERAL GOVERNMENT

░	None
▥	All Minerals
▨	Coal Only
▩	Oil, Gas and Coal Only

1 1/2 0 1 MILE

Multiply miles by 1.609 to obtain kilometers.

ALWAYS THINK SAFETY

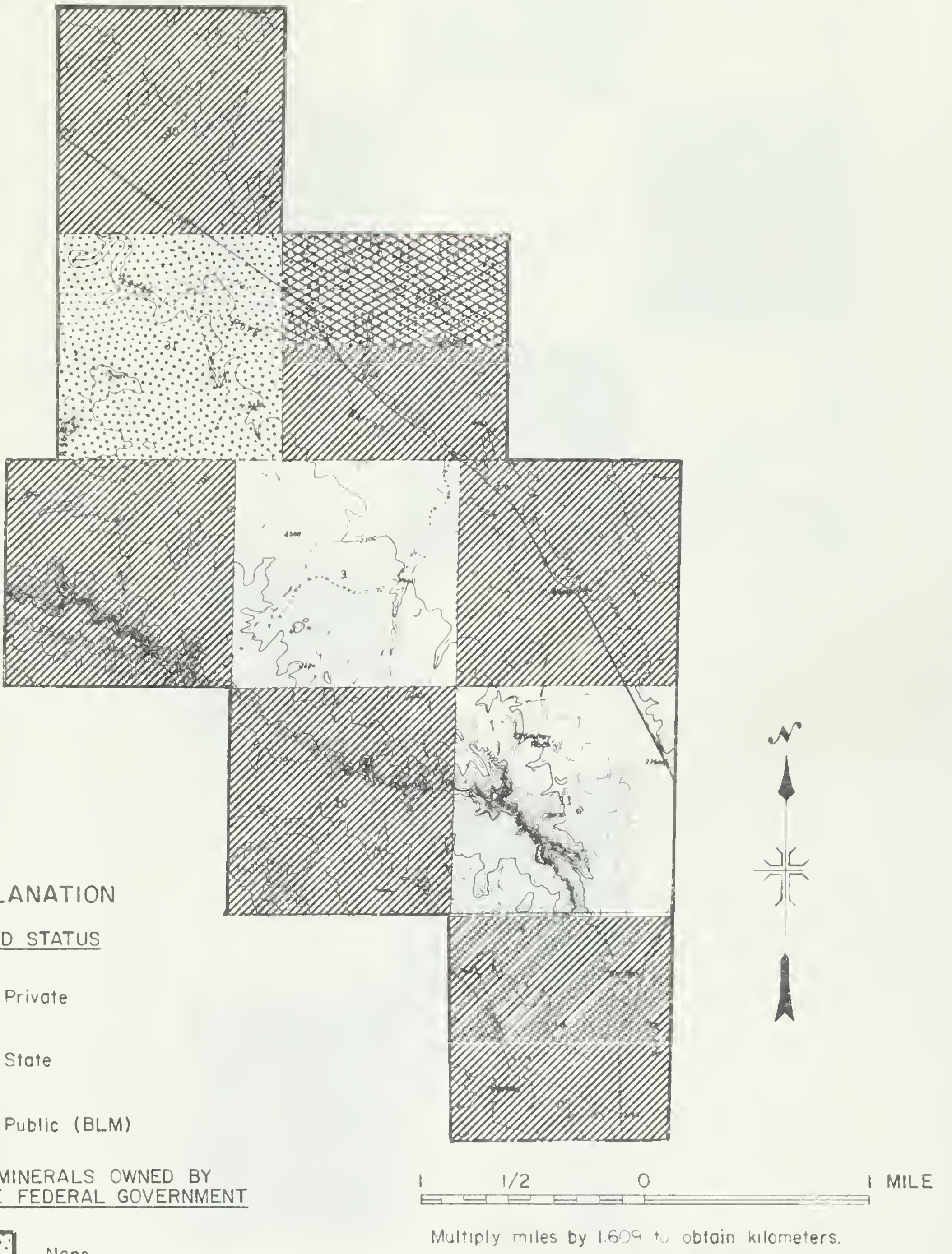
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE AND POTENTIAL RECLAMATION EVALUATION

NORTHEAST MONTANA INVESTIGATIONS
BURNS CREEK STUDY AREA

LAND AND MINERAL STATUS

DESIGNED F. CALCAGNO FIELD APPROVAL
DRAWN S. STARCEVICH TECHNICAL APPROVAL
CHECKED APPROVED
BILLINGS, MONTANA MAY 1983 1305-600-353

Plate 12



Multiply miles by 1.609 to obtain kilometers.

EXPLANATION

LAND STATUS

☐	Private
⁘	State
▢	Public (BLM)

MINERALS OWNED BY THE FEDERAL GOVERNMENT

⁘	None
▥	All Minerals
▨	Coal Only
▩	Oil, Gas and Coal Only

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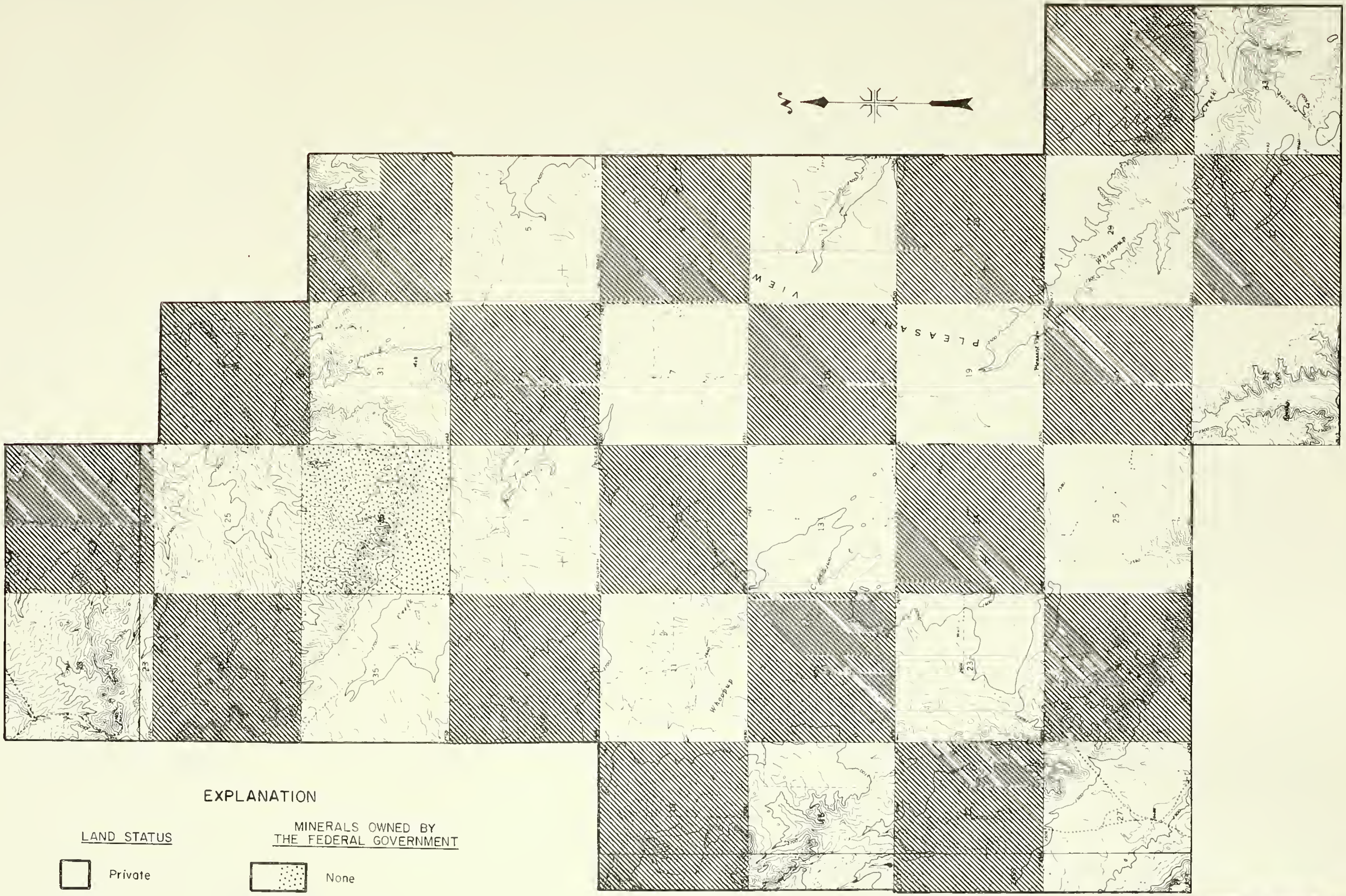
RESOURCE AND POTENTIAL RECLAMATION EVALUATION
NORTHEAST MONTANA INVESTIGATIONS
WOODSON PRLA STUDY AREA

LAND AND MINERAL STATUS

DESIGNED F. CALCAGNO FIELD APPROVAL
DRAWN S. STARCEVICH TECHNICAL APPROVAL
CHECKED APPROVED
BILLINGS, MONTANA MAY 1983 1305-600-354



EXPLANATION

LAND STATUS

- ☐ Private
- ⁙ State
- ▒ Public (BLM)

MINERALS OWNED BY THE FEDERAL GOVERNMENT

- ☐ None
- ▥ All Minerals
- ▨ Coal Only
- ▦ Oil, Gas and Coal Only

1 1/2 0 1 MILE

Multiply miles by 1.609 to obtain kilometers.

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE AND POTENTIAL RECLAMATION EVALUATION

NORTHEAST MONTANA INVESTIGATIONS
SOUTHWEST GLENDIVE STUDY AREA

LAND AND MINERAL STATUS

DRAWN F. CALCAGNO SUBMITTED
TRACED S. STARCEVICH RECOMMENDED
CHECKED APPROVED
BILLINGS, MONTANA MAY 1983 1305-600-355

PHYSICAL PROFILE

CLIMATE[1]

The study areas described in this report have a continental-type, semiarid climate characterized by cold winters, warm summers, and large variations in seasonal precipitation.

Precipitation

The mountains along the Continental Divide cause air masses to rise and precipitate their moisture, primarily on the windward slopes. The air masses then warm and dry as they descend the leeward slopes. As a result, a "rain shadow" is created over Dawson and McCone Counties. The average annual precipitation in these counties is about 13 inches.

Data from two weather stations in Dawson County were used to evaluate precipitation. Glendive, located along the Yellowstone Valley (Elev. - 2076 feet) in the southeast part of the county, records an average annual precipitation of 12.6 inches. Richey, located in the uplands (Elev. - 2476 feet) in the northwest part of the county, averages 13.4 inches of annual precipitation.

About 80 percent of the annual precipitation normally occurs during the growing season, April through September. June is commonly the wettest month.

Table 1 lists the average monthly and annual precipitation values recorded at Glendive and Richey.

Most summer precipitation occurs in showers, although steady, gentle rains do occur in May, June, and September. Thunderstorms, most common in July and August, occasionally produce hail heavy enough to damage crops.

Snowfall usually averages about 28 inches in the Yellowstone Valley and slightly more in the uplands. Heavy snowfalls, though uncommon, may occur infrequently in late winter or early spring.

Temperature

Average daily maximum and minimum temperatures per month as recorded at Glendive and Richey are shown in Table 2.

The frost-free period (>32° F.), lasting from early May through late September, ranges from about 110 days in the uplands to more than 130 days in the Yellowstone Valley. The growing season for hardy crops (>28° F.) ranges from about 120 days in the uplands to as much as 150 days in the Yellowstone Valley. Growth of native range plants and small grains is rapid during May and June. By about mid-July, however, the available soil moisture is usually depleted and the plants mature or become dormant.

1/ From: Soil Survey of Dawson County, Montana, Soil Conservation Service, 1976.

Other Climatic Factors

Winds that cause soil erosion occur about every month. The strongest winds are generally from a westerly direction. Wind speeds exceeding 50 miles per hour or more occur occasionally during thunderstorms or in fall or winter when a weather system crosses the State.

Sunshine is prevalent about 70 to 80 percent of the time during the summer months, being interrupted mostly during afternoon showers or thunderstorms.

Effect of Climate on Revegetation

Climate will be an important controlling factor for revegetation of disturbed lands. Late spring precipitation, coupled with stored moisture from winter precipitation, will provide adequate soil moisture in most years for establishing good stands of native range vegetation, small grains, or other adapted plants.

Revegetation efforts could be severely limited in years receiving less than 10 inches of precipitation. Data recorded at Glendive and Richey indicate about a 20 percent probability (2 years in 10) that this condition could occur.

Specific climatic factors that could adversely affect revegetation include: (1) below normal or uneven distribution of precipitation, especially during the growing season, (2) intense thunderstorms or hailstorms that damage vegetation and/or cause soil erosion, (3) late spring freezes, and (4) depletion of soil moisture by wind. Additional on-site data collection will be necessary prior to mining to more accurately determine probabilities of occurrence of these factors. This data can then be used to select best possible seeding times for revegetation.

Table 1

Average Monthly and Annual Precipitation

Glendive, Montana (1932-1961) 1/

Month

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
						(Inches)						
0.4	0.4	0.6	1.1	1.6	3.1	1.6	1.5	0.9	0.7	0.4	0.3	12.6

Richey, Montana (1948-1969) 2/

Month

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
						(Inches)						
0.4	0.3	0.4	1.2	2.0	2.6	2.2	1.7	1.3	0.6	0.4	0.3	13.4

1/ Elevation - 2076 Feet

2/ Elevation - 2476 Feet

Table 2

Average Daily Maximum and Minimum Temperatures Per Month

Glendive, Montana (Elevation - 2076 Feet) 1/

Month (°F)

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Maximum	27	31	43	60	73	80	90	89	77	64	44	34	59
Minimum	4	6	19	33	44	53	59	56	44	34	21	11	32

Richey, Montana (Elevation - 2476 Feet) 2/

Month (°F)

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Maximum	22	29	37	55	68	76	85	85	73	61	42	30	55
Minimum	0	7	15	29	40	49	55	53	43	32	19	8	29

1/ Recording Period: 1932-1961

2/ Recording Period: 1948-1969

PHYSIOGRAPHY

With one exception, the majority of the five study areas located within the Northeast Montana Investigations are situated in the unglaciated portion of the Great Plains Physiographic Province. The northern portion of the Circle 2 Study Area, however, lies in the glaciated portion of this Physiographic Province.

Two distinct types of topography present in the area are separated by the Missouri-Yellowstone River drainage divide, which trends northeastward across the center of the Investigations area. Southeast of the divide are extensive upland areas consisting of a series of terraces, one-half to 3 miles wide, which extend for many miles along the Yellowstone River. These terrace levels range from 15 to more than 1000 feet above the river. The higher terraces are undulating and are dissected by streams. In some places only isolated gravel topped buttes remain. The lower terraces are broad, with less dissection.

A rugged topography is formed by differential erosion which, in many places, forms badlands and cliffs. The general slope of the area southeast of the Missouri-Yellowstone River drainage divide is to the southeast. The northwest side of the divide is a rough escarpment 60 to 200 feet in height. For the most part, the country northwest of the divide is rolling; however, it often displays varied features such as isolated buttes, small mesas and benches.

The major valleys are wide and open, with broad alluvial flats trenched by stream channels up to 30 feet deep. The alluvial flats are commonly bordered by low bluffs and badlands. Further to the north, the badlands develop into the "breaks" of the Missouri River. In general, the land surface descends northwestward from the divide to the Missouri "breaks."

The maximum relief of the area is approximately 1467 feet, ranging from an elevation of 3467 feet (14 miles southeast of Circle, Montana) along the Missouri-Yellowstone River drainage divide to an approximate elevation of 2000 feet (near Intake, Montana) along the Yellowstone River. Local relief, however, seldom exceeds 300 feet. The topography of the five study areas are shown on Plates 2 through 7.

All of the area located southeast of the Missouri-Yellowstone River drainage divide (including the Upper Thirteenmile, Woodson PRLA, Burns Creek and S.W. Glendive Study Areas) drains into the Yellowstone River, while the area northwest of the divide (including the Circle 2 Study Area) drains into the Missouri River (see Plate 15). The Yellowstone River tributaries are predominantly parallel and flow in a southeasterly direction toward the river. The major Missouri River tributary in the area is Redwater Creek, which flows towards the northeast along with its numerous parallel tributaries.

The tributary streams of the Yellowstone and Missouri Rivers become intermittent during the summer and fall. Although the flow of these streams appears small, it is probable that a considerable amount of water migrates downstream in the alluvial sand and gravel beneath the surface. A few small reservoirs formed by earth dams have been constructed by ranchers to impound surface waters, but much of their water is soon lost through evaporation and seepage.

GEOLOGY

Regional Geology

The five study areas in Dawson and McCone Counties are located on the west edge of the Williston Basin in northeastern Montana. This basin is a synclinal structure with a general northwest-southeast trend extending from South Dakota into Canada, a distance of about 500 miles.

The geologic history of the area since Precambrian time includes periods of deposition, deformation, and erosion. A sequence of carbonates, sandstones, and shales, mostly of marine origin, were deposited throughout Montana during the Paleozoic and Mesozoic Eras. These sediments are about 14,000 feet thick in the deepest part of the Williston Basin.

Deformation of the Rocky Mountains to the west and associated uplifting of the Great Plains area in Montana began with the Laramide Revolution at the close of Cretaceous time. Intermittent uplifting continued through the Paleocene and ended in Eocene time. Materials eroded from the highlands buried the mountain flanks and spread in thick sheets over most of the Great Plains by the middle of the Cenozoic Period. A second regional uplift which occurred during Pliocene and Pleistocene times elevated sediments to their present position. Streams rejuvenated by the uplift began stripping Tertiary strata from the Great Plains and exhuming the buried mountain masses to the west. The prominent preglacial drainages of the area were the ancestral Redwater and Yellowstone Rivers.

During the Pleistocene Epoch, several continental ice sheets advanced into Montana and terminated immediately to the north of the Investigations areas. The extreme northern portion of the Circle 2 Study Area was invaded by at least one ice sheet, and consequently is covered by glacial debris which was deposited during the advance and retreat of glacial ice. A much more pronounced effect of glaciation upon the Northeast Montana Investigations areas were the creation of several proglacial lakes which formed just beyond the outer limits of the frontal moraine or ice sheet; most notably along the valleys of Redwater Creek and the Yellowstone River, which were dammed by the advancing glacial ice.

Today, shales, siltstones, sandstones, and lignite of Upper Cretaceous and Paleocene age are exposed in the east-central part of Montana. Quaternary glacial, proglacial, terrace, eolian, and alluvial deposits mantle the bedrock in parts of the five study areas. Plate 14 is a generalized regional geologic map showing the bedrock and southern limits of glaciation in the area.

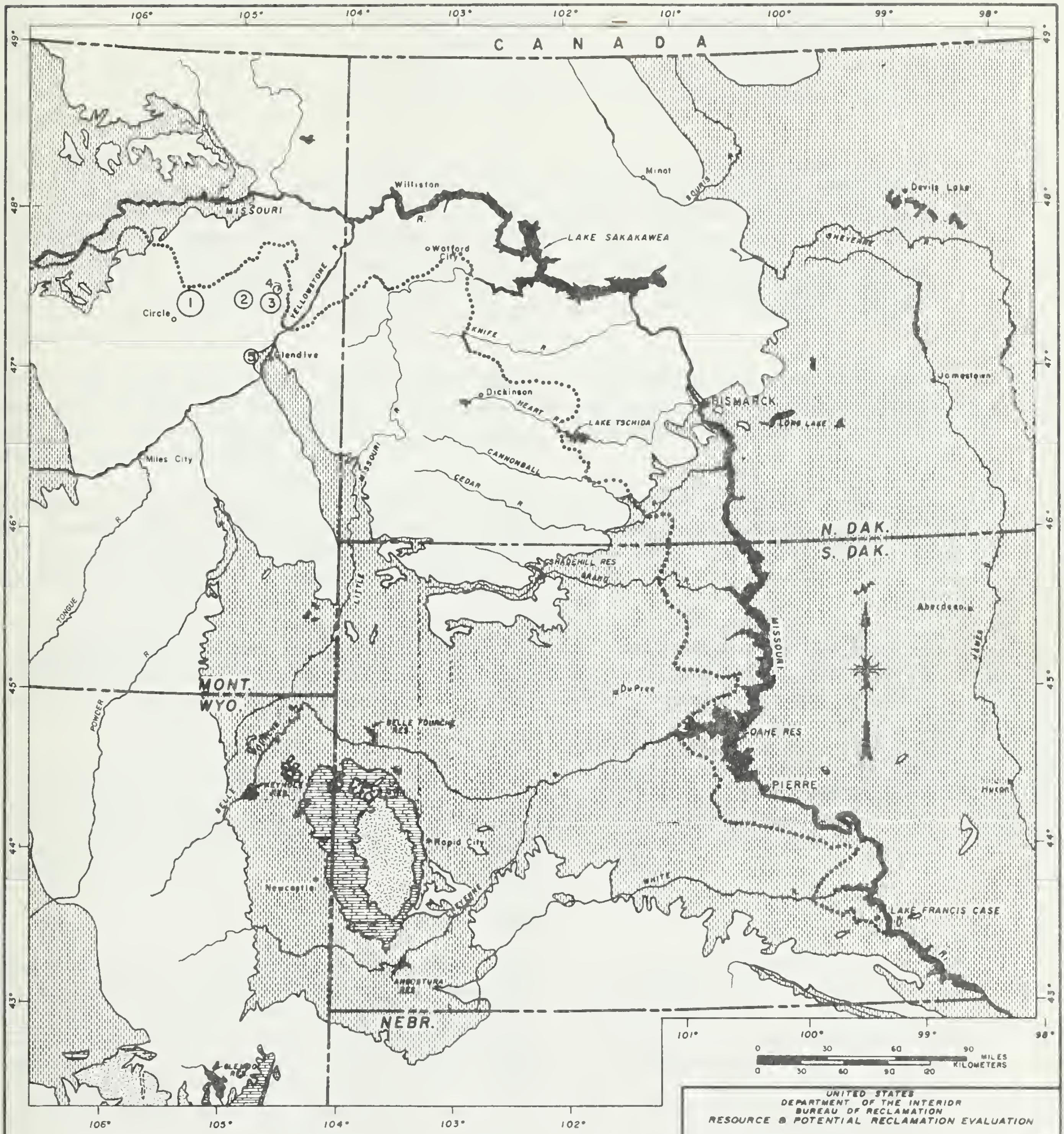
Area Geology

Investigations

Surface and subsurface investigations were conducted by the Bureau of Reclamation in the five study areas in northeastern Montana during the winter and spring of 1981. These investigations included preparing a map of the surface geology and drilling a series of core holes.

Previous geologic investigations covering the area were very useful in preparing this report (see bibliography). Four of the references that were used to prepare the surface geologic map of the area are: (1) Montana Bureau of Mines and

PLATE 14



☐	CENOZOIC
▨	CENOZOIC (IGNEOUS)
▨	MESOZOIC
▨	PALEOZOIC
▨	PRECAMBRIAN

•••.••• SOUTHERN LIMITS OF GLACIATION

①	Circle 2 Study Area
②	Upper Thirteenmile Creek Study Area
③	Burns Creek Study Area
④	Woodson PRLA Study Area
⑤	Southwest Glendive Study Area

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RESOURCE & POTENTIAL RECLAMATION EVALUATION

NORTH DAKOTA, SOUTH DAKOTA, MONTANA & WYOMING
GENERALIZED REGIONAL GEOLOGIC MAP

DESIGNED G. TAUBERT ____ SUBMITTED ______________________
DRAWN L. STARCEVICH ____ RECOMMENDED ______________________
CHECKED G. L. T. ______ APPROVED ______________________

BILLINGS, MONTANA MAY 1983 1305-600-356

Geology, Memoir No. 14, Plate 8, compiled by E.S. Perry, 1935, (2) U.S. Geological Survey Miscellaneous Investigations Map I-327, Glacial Map of Montana East of the Rocky Mountains, by R.B. Colton, et. al., 1961, (3) U.S. Geological Survey Professional Paper 174, Physiography and Glacial Geology of Eastern Montana and Adjacent Areas, by W.C. Alden, 1932; and (4) U.S. Geological Survey, Geologic Map of Montana, by C.P. Ross, et. al., 1955. The surface geologic map (Plate 15) was further modified by incorporating data from the USBR drill holes located in the study areas.

Nine drill holes ranging in depth from 140 to 270 feet were completed in the five study areas. The locations of the drill holes are plotted on the Geologic and Investigations Map, Plate 15. Detailed geologic logs are shown on Plates 16 through 24 in Appendix B. Drilling was performed by Failing 314-C and 1500 rotary drills using wireline tools with an "H" series core barrel. Except for drive sampling in overlying surficial deposits with a Bx casing drive barrel, all drilling was done using bottom discharge core bits with tungsten carbide inserts.

Water was used as a drill fluid in all holes. The organic polymer, "Revert," was used in the drilling fluid in fractured or jointed rock where circulation was lost. After completion, all drill holes in the study area were backfilled with a sand-cement slurry.

Continuous cores were obtained from all holes for geologic logging. The core was immediately placed in boxes and wrapped with plastic to prevent drying until it could be logged and sampled. Samples were taken from representative core material from the study area as follows:

1. Typical overburden (6-inch core lengths) and coal samples (approximately 5-pound bags) from each drill hole were shipped to the U.S. Geological Survey Coal Resources Laboratory in Denver, Colorado. The samples were for their information and test results are not included in this report.

2. Overburden samples of all major stratigraphic units in each drill hole (approximately 8-pound bags) were tested for suitability in reconstructed profiles by Bureau of Reclamation Soils Laboratories in Bismarck, North Dakota, and Boise, Idaho. Test results are graphically shown on the geologic logs (Plates 16 through 24, Appendix B) and listed in Tables 11 through 19, Appendix C.

Stratigraphy

The oldest rocks exposed near the study areas are of Upper Cretaceous age. The Cretaceous Pierre Shale, Fox Hills Sandstone, and the Hell Creek Formation crop out along the Cedar Creek Anticline near Glendive, Montana, and occur immediately to the east of the Southwest Glendive Study Area. The only bedrock unit exposed in the five study areas is the overlying Paleocene Fort Union Formation. In Montana, the Fort Union Formation is divided into the Tullock Member (lower), the Lebo Shale (middle), and the Tongue River Member (upper). Of these, only the Lebo Shale and the Tongue River Member are exposed in the five individual study areas. The Fort Union Formation is stratigraphically overlain by the Eocene Wasatch Formation, which has been entirely removed from the area by erosion. In northeastern Montana, the Fort Union sandstones, siltstones, shales and lignite beds are locally overlain by Miocene (Pliocene?) to Pleistocene gravel terrace deposits, Pleistocene glacial till, glacial and proglacial outwash deposits, proglacial lake deposits, and Holocene alluvium (Plate 15).

Pierre Shale - Cretaceous

The Pierre Shale is exposed along the Yellowstone River valley to the east of the Southwest Glendive Study Area, in the southern portion of T. 15 N., R. 55 E., and the eastern portion of T. 15 N., R. 54 E. The Pierre Shale is a dark gray, bentonitic marine shale with an upper sandy part. Hence, the transition between the Pierre and the overlying Fox Hills Sandstone is gradational. The upper part of the Pierre Shale is approximately equivalent to the Bearpaw Shale which crops out extensively in east-central Montana. In eastern Montana, the Pierre Shale is about 1000 feet thick.

Fox Hills Sandstone - Cretaceous

The Fox Hills is exposed along the Yellowstone River in the eastern portion of T. 15 N., R. 54 E., the northern part of T. 15 N., R. 55 E., the southern part of T. 16 N., R. 55 E., and the western part of T. 15 N., R. 56 E. The lower part of the Fox Hills is composed of yellow shaly sandstone interbedded with gray silty sandstone, and the upper part is a massive white to light gray fine- to medium-grained sandstone. The Fox Hills sandstone attains a thickness of approximately 200 feet in the area.

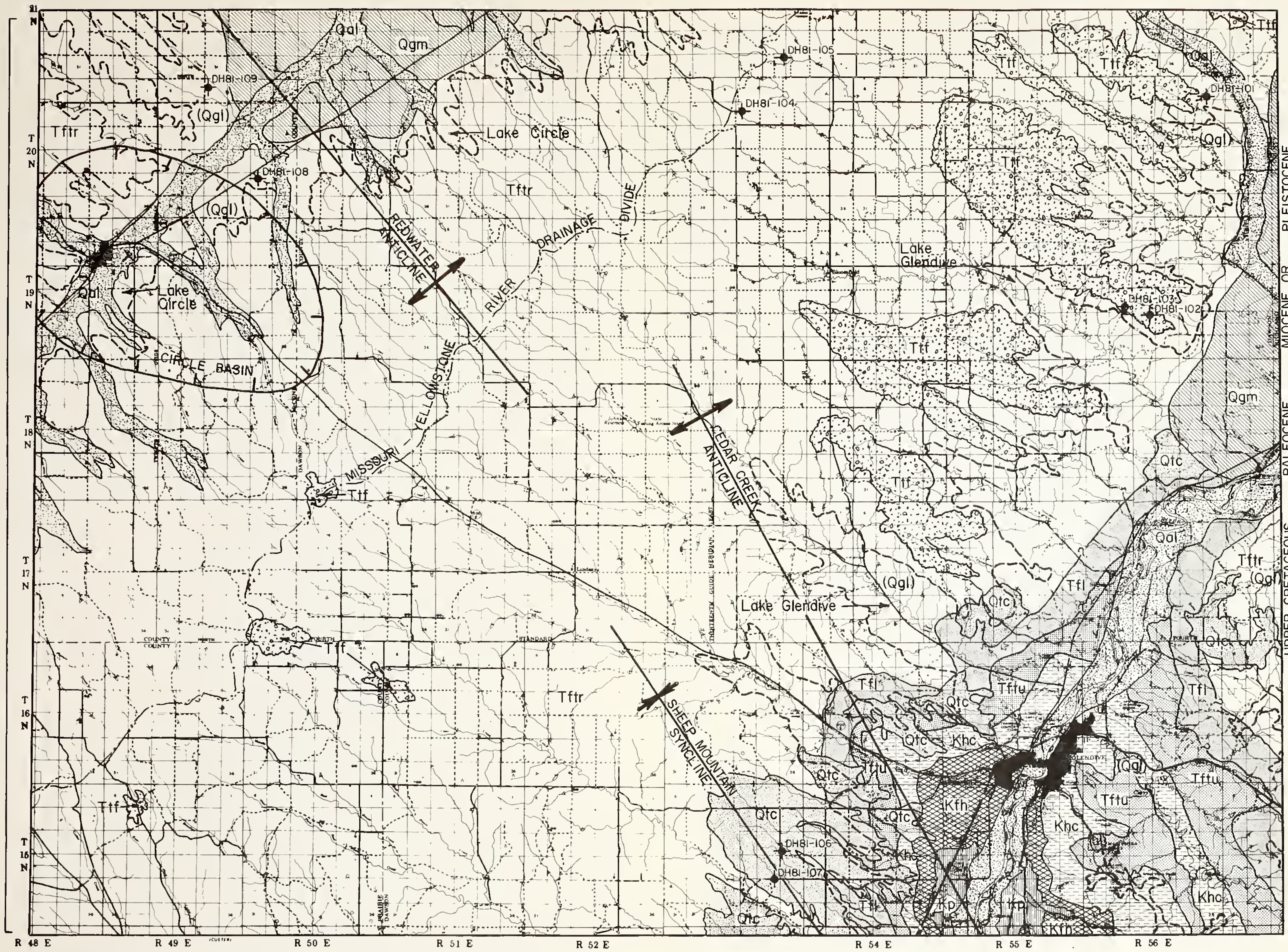
Hell Creek Formation - Cretaceous

The Hell Creek Formation (not exposed in any of the five study areas) crops out in a belt around the plunging nose of the Cedar Creek Anticline within T. 15 N., Ranges 54, 55, and 56 E., and T. 16 N., Ranges 54, 55, and 56 E. The Hell Creek consists of brownish gray sandstone interbedded with carbonaceous shale and gray silty mudstone. Shaly lignite is also present. The Hell Creek Formation attains a thickness of approximately 500 feet in eastern Montana.

Fort Union Formation - Paleocene

Tullock Member - The Tullock Member is the lowest unit of the Fort Union Formation and crops out along the valley of the Yellowstone River in an arcuate belt surrounding Glendive, Montana (Plate 15). It consists of an alternating sequence of uncemented, fine-grained, tan to light gray sandstone, medium gray clay shale, and black carbonaceous shale. The dark carbonaceous shale commonly has streaks and thin beds of lignite from 5 to 30 feet apart. The Tullock Member does not crop out in any of the five study areas. The Tullock is approximately 200 feet thick in the area.

Lebo Shale Member - The Lebo Shale is the oldest member of the Fort Union Formation exposed in any of the study areas (Southwest Glendive Study Area, Plate 15). The Lebo consists of predominantly dark shales interbedded with brown to black carbonaceous shale, siltstone, and locally thin coalbeds. Shales contain altered and devitrified volcanic ash and reddish brown ferruginous concretions. White to light gray, argillaceous, crossbedded, and lenticular sandstones occur locally. The Lebo Shale generally erodes to large flat plains due to the lack of resistant horizons. This member commonly supports sparse vegetation. The Lebo Shale is approximately 300 feet thick.



EXPLANATION

HOLOCENE	Qal	ALLUVIUM	Unconsolidated sand, silt, and gravel. Locally contains buried Pleistocene/Holocene outwash channel deposits.
PLEISTOCENE	(Qgl)	PROGLACIAL LACUSTRINE	Unconsolidated sand, silt, and clay lake deposits formed at the outer margin of glacial advance. Dashed line shows outer limit; locally absent due to erosion.
	Qgm	GLACIAL TILL	Morainal deposits of clay, silt, sand, and boulders deposited by advancing and/or retreating glaciers.
	Qtc	CARTWRIGHT GRAVEL TERRACE	Unconsolidated silt, sand, gravel, and cobble deposits up to 90 feet thick. Base of deposit has a downward gradient toward Yellowstone River. (Third Cartwright terrace.)
MIOCENE OR PLIOCENE	Ttf	FLAXVILLE GRAVEL TERRACE	Unconsolidated to locally cemented sand, gravel, cobbles, and volcanic ash deposited on a planated erosional surface. Flaxville Plain extends to higher elevations and may locally contain isolated gravel deposits. About 30 feet thick.
PALEOCENE, FORT UNION Fm.	Tftr	TONGUE RIVER MEMBER	Interbedded shale, siltstone, sandstone, and lignite. About 900 feet thick. Includes baked sediments (clinker) produced by burning of coal-beds.
	Tfl	LEBO SHALE MEMBER	Dark shale, interbedded carbonaceous shale, siltstone, thin lignite beds, and sandstone. About 300 feet thick.
	Tftu	TULLOCK MEMBER	Generally uncemented sandstone with clay shale, carbonaceous shale, siltstone, and some lignite. About 200 feet thick.
UPPER CRETACEOUS	Khc	HELL CREEK FORMATION	Moderately cemented, discontinuous sandstone, shale, clay shale, and thin limestone beds. About 500 feet thick.
	Kfh	FOX HILLS SANDSTONE	Moderately cemented sandstone, shaly sandstone, and silty sandstone. About 200 feet thick.
	Kp	PIERRE SHALE	Dark gray, bentonitic shale with calcareous and ferruginous concretions, and sandy members. About 1000 feet thick.

Geologic contact. Queried where estimated.

Extreme limit of proglacial lake deposits.

Missouri-Yellowstone River drainage divide.

◆ USBR Drill Hole.

Anticline

Syncline

Minor structural basin

2 1 0 1 2 3 4 5 6
SCALE OF MILES

N

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NORTHEAST MONTANA INVESTIGATIONS

GEOLOGIC & INVESTIGATIONS MAP

GEOLOGY F. CALCAGNO FIELD APPROVAL
DRAWN S STARCEVICH TECHNICAL APPROVAL
CHECKED APPROVED

BILLINGS, MONTANA MAY 1983 1305-600-357

Tongue River Member - The Tongue River Member is the uppermost member of the Fort Union Formation, and crops out in all five of the individual study areas (Plate 15). The Tongue River Member consists of an alternating sequence of sandstone, siltstone, shale, carbonaceous shale and coal with thin calcareous or siliceous cemented concretions. In general, the sandstones are fine-grained and uncemented except for lenticular, concretionary masses of small lateral extent. Shales vary from soft, plastic clayshale to moderately indurated claystone. The shale and siltstone zones break down readily and form slopes below sandstone ledges. Correlation of clastic sediments over short distances is difficult due to facies changes, channeling, and variation in bedding thickness. Laboratory analyses conducted on core samples from other study areas indicate that chemical and physical properties of the bedrock cannot generally be projected between drill holes. Weathered exposures are pale olive or yellowish gray in color, while fresh core samples vary from light to dark gray. The Tongue River sediments were deposited in a continental environment which included swamps conducive to the production of thick coalbeds. Coal and carbonaceous zones serve as excellent marker beds as they can generally be traced laterally over great distances. The Tongue River Member attains a thickness of approximately 900 feet in the area.

One striking feature of the Fort Union Formation is the resistant clinker zones, locally called "scoria," that cap ridges and buttes or armor valley walls. The clinker, which is fused or baked rock, was produced by the burning of coalbeds along and back from the outcrops. In places where the heat was sufficiently intense, the clinker has been fused to a dark-gray, lightweight rock similar in appearance to vesicular basalt. Near the outer edge of thermal metamorphism, the rock is disoriented, baked, and red to orange in color. Alteration of the overlying material is roughly twice to the original thickness of coal that has burned. A coalbed 30 feet thick will produce clinker zones 50 to 75 feet thick. The clinker is highly permeable and locally supplies water for springs and wells.

Wasatch Formation - Eocene

The Fort Union Formation is stratigraphically overlain by the Wasatch Formation of Eocene age. These sediments have been eroded from the study area but crop out in southeastern Montana. Its' stratigraphic equivalent (the Golden Valley Formation) is also present in isolated areas in west central North Dakota. The Wasatch Formation consists of light colored thin bedded to massive sandstone, drab colored shale and coal.

Flaxville Gravel - Miocene or Pliocene

The Flaxville Gravel caps remnants of the formerly extensive peneplain surface, called the Flaxville Plain. Although limits are delineated for the Flaxville Gravel on Plate 15, isolated patches of the gravel can also be expected to crop out at higher elevations along the divide between the Yellowstone and Missouri Rivers. Where the Flaxville gravel occurs south of the limits of continental glaciation, the terrace deposits are overlain by a thin mantle of eolian material. The Flaxville is composed of unconsolidated to locally cemented (calcium carbonate) rounded cobbles, gravel, sand, and volcanic ash. The base of the Flaxville Gravel has a gentle downgradient toward the Yellowstone River and lies approximately 650 feet above the river northwest of the city of Glendive.

Cartwright Gravel - Pleistocene

The Cartwright Gravel was deposited by the preglacial Missouri and Yellowstone Rivers and their tributaries on the Missouri Plateau peneplain erosional surface. The Cartwright is largely confined to the broad upland area between the Missouri-Yellowstone River drainage divide and the Yellowstone River valley. Plate 15 identifies the Cartwright Gravel as only occurring in the Southwest Glendive Study Area; however, it extends to the northeast along the Yellowstone River at approximately the same elevation. Similar to the Flaxville Gravel, the Cartwright is overlain by eolian material in areas south and west of the furthest glacial advance. The Cartwright is composed of unconsolidated silt, sand, gravel, and cobbles, which in part may be reworked Flaxville material. However, the Cartwright also commonly contains clinker and soft Fort Union Formation sandstones. The Cartwright, although undifferentiated on Plate 15, contains up to four distinct terrace levels from 170 to 600 feet above the Yellowstone River. The Cartwright Gravel attains a thickness of up to 90 feet in the Southwest Glendive Study Area. Although not shown on Plate 15, up to four lower gravel terrace levels (including the Crane Creek) are present at lower elevations and nearer to the Yellowstone River valley, from 12 to 50 feet above the present level of the river.

Glacial Till - Pleistocene

The glacial till deposits consist of a heterogeneous mixture of clay, silt, sand, gravel, cobbles, and boulders deposited by one or more continental glaciers. The maximum extent of glaciation terminated immediately to the north and northeast of the study areas (Plate 15). The northeastern portion of the Circle 2 Study Area is the only one of the five study areas to contain glacial till deposits. Where it occurs, it ranges from a thin veneer covering the higher topographic surfaces to over 100 feet thick where it was deposited in preglacial valleys. Buried outwash channels of silt and sand can be expected to occur within the till deposits as well.

Proglacial Lacustrine - Pleistocene

During glaciation, advances of ice and the resulting deposition of till over preexisting drainages (Redwater Creek and Yellowstone River) caused a natural damming-up of the streams which resulted in the creation of proglacial Lakes Circle and Glendive. Plate 15 shows the maximum extent of these lakes within the Northeastern Montana Investigations Study Areas. Portions of the Circle 2 Study Area lie within the boundaries of proglacial Lake Circle, while portions of the Southwest Glendive, Burns Creek, and Woodson PRLA Study Areas lie within the boundaries of proglacial Lake Glendive. Although the maximum extent of the proglacial lakes are shown on Plate 15, consequent erosion has locally removed the fine sand, silt, and clay deposited by the lakes. After glaciation, consequent erosion breached the natural dams and drained the short-lived lakes.

Windblown (loess) - Pleistocene and Holocene

Windblown silt and sand are locally present in the area and overlie every type of deposit. These deposits are thin and discontinuous and are not shown on the geologic map (Plate 15).

Alluvium - Holocene

Alluvial deposits consist of unconsolidated clay, silt, sand, and gravel that cover the modern valley floors in the area. Although it is present in most of the small valleys of the area, it was only mapped along the major drainage systems. The alluvium is as much as 30 feet thick in steeply cut banks along entrenched stream valleys, and may exceed 100 feet thick in the Yellowstone Valley. Locally, the alluvium may contain buried Pleistocene outwash channel deposits and lower level gravel terrace deposits.

Structure

The study areas within the Northeast Montana Investigations lie on the western flank of the Williston basin. The southern part of the area is on the plunging nose of the Cedar Creek Anticline, a long linear uplift whose axis trends northwest and passes about 8 miles southwest of Glendive, Montana. The Sheep Mountain Syncline is located to the southwest and parallels the Cedar Creek Anticline. The Sheep Mountain Syncline approaches the center of the Investigations area and may correlate with the Blood Creek Syncline which trends predominantly westward, located to the south of Circle, Montana. Near the intersection of the Blood Creek Syncline with the Sheep Mountain Syncline lies a small structural basin called the Circle basin. Bordering the Circle basin to the northeast is the Redwater Anticline, which similar to the Cedar Creek Anticline, trends northwest. Plate 15 shows the location of all the structural features of the area.

The dip of the beds in the area is slight, generally ranging from 10 to 50 feet per mile but increasing to as much as 250 feet per mile near local structures. The direction of the dip is toward the center of the Williston basin which is predominantly northeastward for the majority of the area and southeastward near Circle, Montana.

Small local faults are common in the weak, plastic, carbonaceous shales immediately above or below lignite beds contained within the Fort Union Formation. Displacements along these fractures probably do not exceed 5 feet; however, Banet (1979) notes the presence of possibly large normal faults in Sec. 23, T. 17 N., R. 53 E., and Sec. 7, 8, 17, 18, and 29, T. 16 N., R. 54 E., of indeterminate displacement.

Paleontology

Geologic investigations did not reveal any significant or unusual paleontological sites in the study areas. Fossils found in drill core samples included calcareous shell fragments (pelecypod ?). Plant fossils found consisted of carbonaceous impressions of leaves and twigs. None of these were collected for identification.

Mineral Resources

An important economic resource of the area at the present time is petroleum. Oil and gas reserves have largely been recovered from Paleozoic rocks at depths of 9,000 to 13,000 feet.

Lignite is also an important economic resource found in the five study areas. Lignite has been mined in northeastern Montana on a small scale for a number of years. There are several lignite beds in the area thick enough to economically mine along with numerous very thin beds and stringers. Further information concerning lignite is presented later in this report.

Other minerals of minor economic significance which have been produced within the area include bentonite from bentonitic shales of the Fort Union Formation, sand and gravel from terrace or alluvium deposits, and baked shale (scoria) from above burned out coalbeds in the Tongue River Member of the Fort Union Formation.

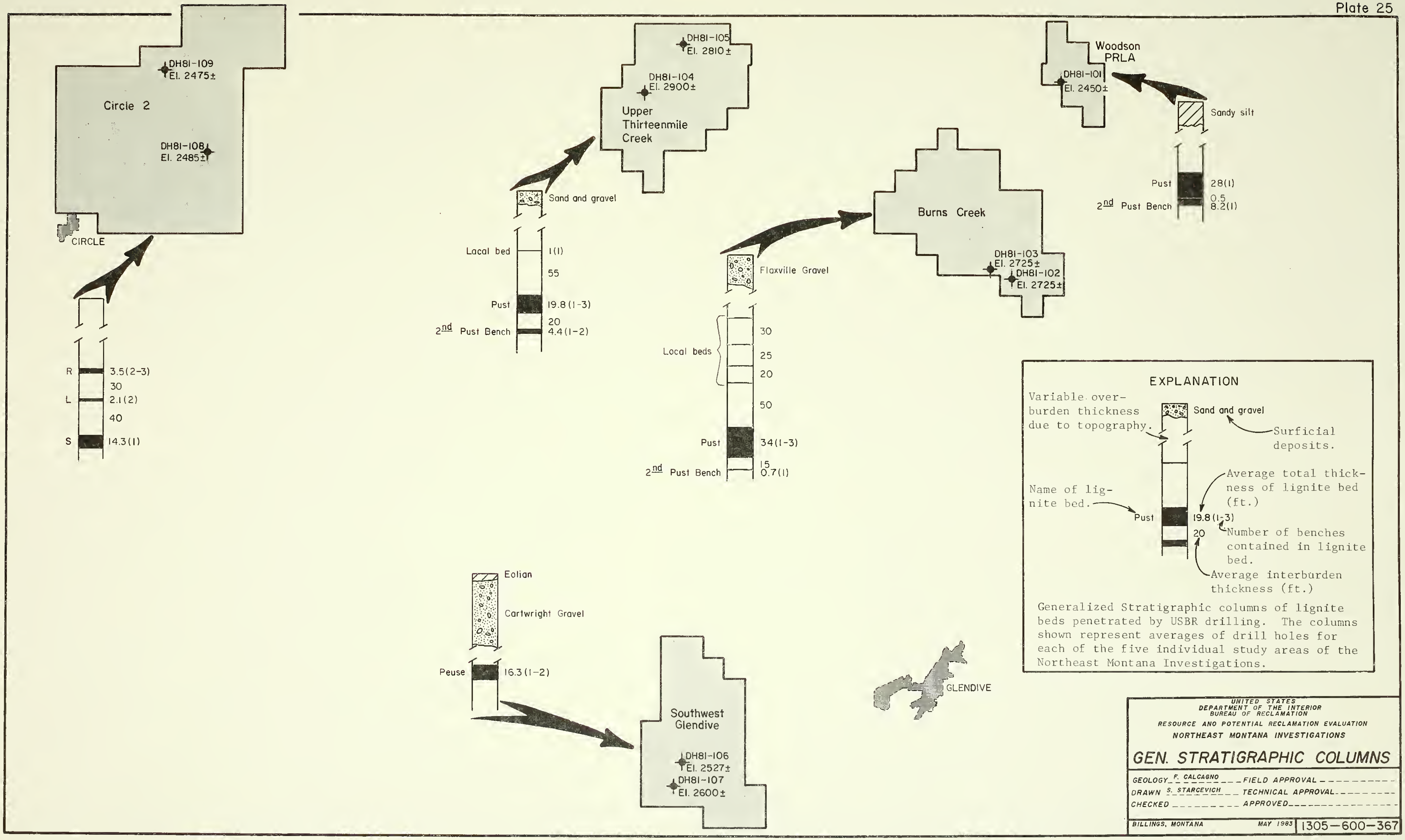
Lignite Beds

Approximately 15 lignite beds greater than 0.4 foot thick were penetrated by U.S. Bureau of Reclamation drilling within the Northeast Montana Investigations. No one drill hole penetrated all lignite beds. Of these, six continuous beds are present, four of which are fairly thick. The remaining beds are of varying thickness and have little continuity. Additionally, several zones were penetrated containing thin, wispy lignitic laminations (often crossbedded) which may correlate with thin lignite beds in other locations. The six major lignite beds, from oldest to youngest, that were penetrated by drilling are: (1) S-bed; (2) L-bed; (3) R-bed; (4) Second Pust Bench; (5) Pust; and (6) Peuse. Plate 25 shows the general stratigraphic sections of the major lignite beds encountered in the five study areas.

Due to the wide spacing of drill hole information of the present study, coal resource data and structure/overburden contours were not be determined. The U.S. Geological Survey, however, has provided coal resource data for several of the individual study areas. The following U.S.G.S. Open File Reports provide coal resource data for the following areas: (1) U.S.G.S. Open File Report 76-617 (Spencer, 1976) (Burns Creek - Thirteenmile Creek); (2) U.S.G.S. Open File Report 78-367 (Wincentsen, 1978) (Circle); and (3) U.S.G.S. Open File Report 79-275 (Banet, 1979) (West Glendive). The remainder of this section will discuss the general trends of the lignite deposits found in the five individual study areas of the Northeast Montana Investigations based on the data from the nine USBR drill holes.

S-, L-, R- Beds - The S-, L-, and R-beds were the only significant lignite beds encountered by U.S. Bureau of Reclamation drilling in the Circle 2 Study Area. Within the Circle 2 Study Area the S-bed attains an average thickness of 14.3 feet (from 10.1 to 18.4 feet). Approximately 40 feet above the S-bed lies the L-bed. The L-bed ranges in thickness from 0.6 to 3.5 feet thick (average thickness of 2.1 feet) and is found in two benches (average interburden of 9 feet). The R-bed lies approximately 30 feet above the L-bed and attains an average thickness of 3.5 feet (from 2.5 to 4.4 feet). The R-bed is found in two to three benches, with an average interburden thickness of 6.7 feet.

Second Pust Bench - The Second Pust Bench was encountered in the Upper Thirteenmile Creek, Woodson PRLA, and Burns Creek Study Areas. The Second Pust Bench attains a thickness of approximately 8.2 feet in the Woodson PRLA Study Area and 0.7 feet thick in the Burns Creek Study Area. Within the Thirteenmile Creek Study Area, this bed averages 4.4 feet thick (from 7.7 to 1.0 feet) and contains up to two benches (average interburden of 1.1 feet). The Second Pust Bench lies approximately 400 feet above the R-bed.



Generalized Stratigraphic columns of lignite beds penetrated by USBR drilling. The columns shown represent averages of drill holes for each of the five individual study areas of the Northeast Montana Investigations.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE AND POTENTIAL RECLAMATION EVALUATION
NORTHEAST MONTANA INVESTIGATIONS

GEN. STRATIGRAPHIC COLUMNS

GEOLOGY F. CALCAGNO FIELD APPROVAL
DRAWN S. STARCEVICH TECHNICAL APPROVAL
CHECKED APPROVED
BILLINGS, MONTANA MAY 1983 1305-600-367

Pust Bed - The Pust lignite bed lies from 0.5 to 24.1 feet (average 13 feet) above the Second Pust Bench. The Pust bed is the thickest and most continuous of the lignite beds in the area, and attains a thickness of 28.0 feet in the Woodson PRLA Study Area, an average thickness of 19.8 feet (from 17.3 to 22.3 feet) in the Upper Thirteenmile Creek Study Area, and an average thickness of 34.0 feet (from 33.6 to 34.3 feet) in the Burns Creek Study Area. The Pust Bed contains three benches in the Upper Thirteenmile Creek and Burns Creek Study Areas with respective average interburden thicknesses of 4.9 feet and 4.6 feet.

Prichard and Landis (1975) indicate that the Pust lignite bed is very extensively burned (clinkered) along its outcrop to as much as 50 feet thick in T. 21 N., R. 56 E. Culbertson (1954), in describing the Pust bed immediately to the north of the Northeastern Montana Investigations Study Areas, places the Pust about 525 feet above the base of the Tongue River Member of the Fort Union Formation.

Peuse Bed - The Peuse bed, as described by Banet (1979), was encountered in the Southwest Glendive Study Area. Here, the Peuse attains an average thickness of 16.3 feet (from 15.4 to 17.1 feet). The Peuse contains from one to two benches, with an average interburden thickness of 0.6 feet. The Peuse lignite bed encountered in the Southwest Glendive Study Area may correlate to the Pust bed further to the northeast.

Engineering Geology

Stability of Excavation Slopes

Engineering property tests were not conducted on bedrock samples from the study areas within the Northeast Montana Investigations. The physical property test results for this study area should be similar to those of Fort Union Formation samples tested at the Otter Creek Study Site, Montana (EMRIA Report No. 1).

Shear strengths of the material are low, especially in a saturated condition. Slides could easily develop adjacent to high walls in surface mines, particularly along beds of weak, plastic, carbonaceous shales which are typically cut by inherent slickensides. Adequate drainage will have to be maintained to relieve pore water pressure in the overburden as mine excavations progress.

Saturated, uncemented siltstones and fine-grained sandstones will readily erode and flow into excavations. This problem is sometimes encountered in drilling when the walls of holes collapse or slough. Depth of excavation will be limited by the water table until these materials are dewatered.

Excavation slopes will vary considerably between mine sites and will be dependent on exposure time, moisture conditions, material types, and depth of cut. Detailed engineering studies of the overburden will be required at each location for use in determination of designed slopes.

Studies conducted at the Otter Creek site indicate that disturbed overburden (spoil banks and piles) should have slopes not greater than 4 to 1 with berms of 50 to 100 feet in width designed on the slope surface.

Overburden Expansion

Overburden volumes expand as the materials are broken up during mining. The increase in volume (bulking or swell) differs for various types of soil and rock. Soft sandstones and shales in the Fort Union Formation will probably expand about 25 percent. In some cases, the surface of the replaced overburden will be higher after mining than the ground surface was before disturbance.

Instability of the Postmining Landscape[1]

Three types of instability are common on reclaimed coal mined areas in the Northern Great Plains. They are: (1) area-wide settling; (2) localized collapse; and (3) piping. Each type of instability is affected by variables in the postmining landscape. These include the physical and chemical characteristics of the overburden, methods and equipment used in stripping and contouring operations, and the season when these activities occur.

Area-wide settling is common in most postmining landscapes, but appears to cause only minimal disruption. This settlement will generally be most pronounced during the first year and will continue at a decreasing rate with the progression of time.

The texture of the overburden will have a marked influence on settlement. Fine-textured (clayey) overburden usually results in a more blocky and, initially, more porous spoils than does coarse-textured (sandy) overburden. Therefore, a lesser degree of settlement is expected in areas of largely sandy spoils than in areas of clayey spoils.

Equipment is also a critical factor. Settlement is significantly less in scraper-contoured areas than in dozer-contoured areas, especially if contouring is conducted in midwinter. This is because a greater degree of compaction is achieved in scraper-contouring operations than in dozer-contouring operations.

Local collapse features develop soon after contouring and usually complete development within a year. They commonly occur in precontouring valley areas where frozen spoil blocks are concentrated by final, midwinter dozer contouring. Thawing of these blocks results in local surface subsidence. In contrast, areas contoured in midwinter with a scraper are stable because large blocks of frozen spoil are broken apart, spread, and compacted. This type of landscape instability is, therefore, largely equipment and seasonally controlled.

Piping appears to be a severe and long-term problem in some postmining landscapes. Development usually begins soon after contouring and may continue for several years. In some postmining landscapes, piping has only started to develop after as much as 5 years of apparent stability. It is controlled by a combination of physical and chemical conditions in the spoils.

A key factor in the development of piping features is the cracking of spoils in areas containing highly dispersive sodic material. These cracks allow access for large volumes of surface runoff to flow into the subsurface. Piping generally develops on nearly flat slopes where surface runoff is minimal and infiltration is maximized.

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[1] Groenewold, G.H., and Rehm, B.W., 1980.

Piping, like other instability problems, most commonly develops in areas contoured by dozers. Scraper-contoured areas generally are better compacted, thus providing fewer subsurface avenues for infiltration of surface water.

Weathering

Weathering tests were not performed on core samples collected in study areas of the Northeast Montana Investigations. However, weathering tests were conducted on similar materials from the Fort Union Formation that were collected at several locations within Montana and North Dakota. These weathering tests revealed that shales break down more rapidly than either sandstones or siltstones but the material produced may be difficult to move and place because of its plasticity.

Seismicity

The Yellowstone Park area is the most active seismic region within 350 miles of the Northeast Montana Investigations area. The largest earthquake (7.1 Richter) recorded in this area occurred at Hebgen Lake, Montana, on August 17, 1959, a distance of about 350 miles from the Investigations area. Although considerable damage occurred near the epicenter, the quake was not readily noticed in the Williston Basin. Forty-five earthquakes of moderate intensity (V to VII on the Modified Mercalli Intensity Scale) have occurred in Wyoming since 1894. Most of these have been centered in the northwestern part of the State. Between 1900 and the end of 1970, there were 113 earthquakes of Intensity V or greater reported in Montana. The majority of these quakes occurred in the southwestern part of the State. No earthquakes of Intensity V or greater (MM) have occurred within North Dakota during historical times; however, an Intensity IV (MM) occurred in Williston, North Dakota, on October 26, 1946, at a distance of 67 miles from the study area.

The Northeast Montana Investigations Study Areas are located in the Algermission Seismic Risk Zone 1 in which minor damage could result to structures from Intensity V to VI (Modified Mercalli Intensity Scale) earthquake shocks. Earthquakes with intensities of V or greater that have occurred during historic times within 250 miles of the site are listed below:

Date	Intensity (Modified Mercalli)	Distance from Northeastern Montana Investigations	Located Near
Oct. 11, 1905	IV-V (2)	225	Hill City - Keystone, SD
May 15, 1909	Unknown	Unknown	Saskatchewan, Canada
Nov. 17, 1925	V	210	Bighorn, WY
Nov. 16, 1928	V	225	Custer, SD
June 24, 1943	VI	80	Froid, MT
June 26, 1966	VI	230	Rapid City, SD

SOIL AND OVERBURDEN

Principal Soil Bodies

This section briefly describes the major soil categories occurring in the Southwest Glendive, Upper Thirteenmile Creek, and Woodson PRLA Study Areas in northeastern Montana. Representative sections within these study areas were classified[1] by the Bureau of Reclamation (USBR) as to their suitability for reclamation and revegetation. Two other study areas described in this report, Burns Creek and Circle 2, were not classified by the USBR and are, therefore, not included in this discussion.

Three major soil categories are common to the Southwest Glendive, Upper Thirteenmile Creek, and Woodson PRLA Study Areas. These are: (1) soils developing in old alluvium on ancient terraces of the Yellowstone River, (2) soils forming in recent alluvium on fans and footslopes and in swales and drainage bottoms, and (3) soils developing in residual sandstone, siltstone, shale, or baked rock (scoria) on ridges and sideslopes. The occurrence of these three categories in each of the study areas is described below.

Southwest Glendive Study Area

Representative sections 14 and 22, T. 15 N., R. 53 E., were classified by the USBR (see Photograph 1).

Soils developing in old alluvium cover almost all of section 14, as well as a small portion in the northeast corner of section 22. These soils occur on a nearly level to undulating high terrace (Pleasant View Flat) of the ancient Yellowstone River.

Typically, the A horizon of these soils is a dark colored loam or gravelly loam, 4 to 6 inches thick. Below this is a moderately developed B horizon 6 to 18 inches thick of very fine sandy loam, silt loam, or clay loam texture. The underlying C horizons consist of medium textured alluvium which grades into coarse sand and gravel deposits or soft sedimentary beds at depths ranging from 12 to 84 inches. The A and B horizons are nonsaline and nonsodic; locally, the C horizons are moderately saline. These soils are used for dryfarm small grain production on gentle and moderate slopes; steeper slopes adjacent to eroded highs are used for range. Table 3, Appendix C, is a "Point Site" soil profile representative of this soil category.

Soils developing in recent alluvium occur on about 50 percent of section 22 and a small portion in the northeast corner of section 14. These soils occupy nearly level to moderately sloping fans, footslopes, swales, and narrow drainage bottoms.

The A horizon of these soils is commonly a dark colored loam or silt loam, 6 to 8 inches thick. A structural B horizon is often absent, characterizing the youthful development stage of these soils. When a B horizon is present, it is weakly developed and clay skins are not well developed on ped surfaces. The C horizons consist of loamy alluvium ranging in thickness from about 2 feet to over 10 feet. The A horizon is usually nonsaline and nonsodic. Locally, the C horizons and underlying sedimentary beds are moderately to strongly saline and

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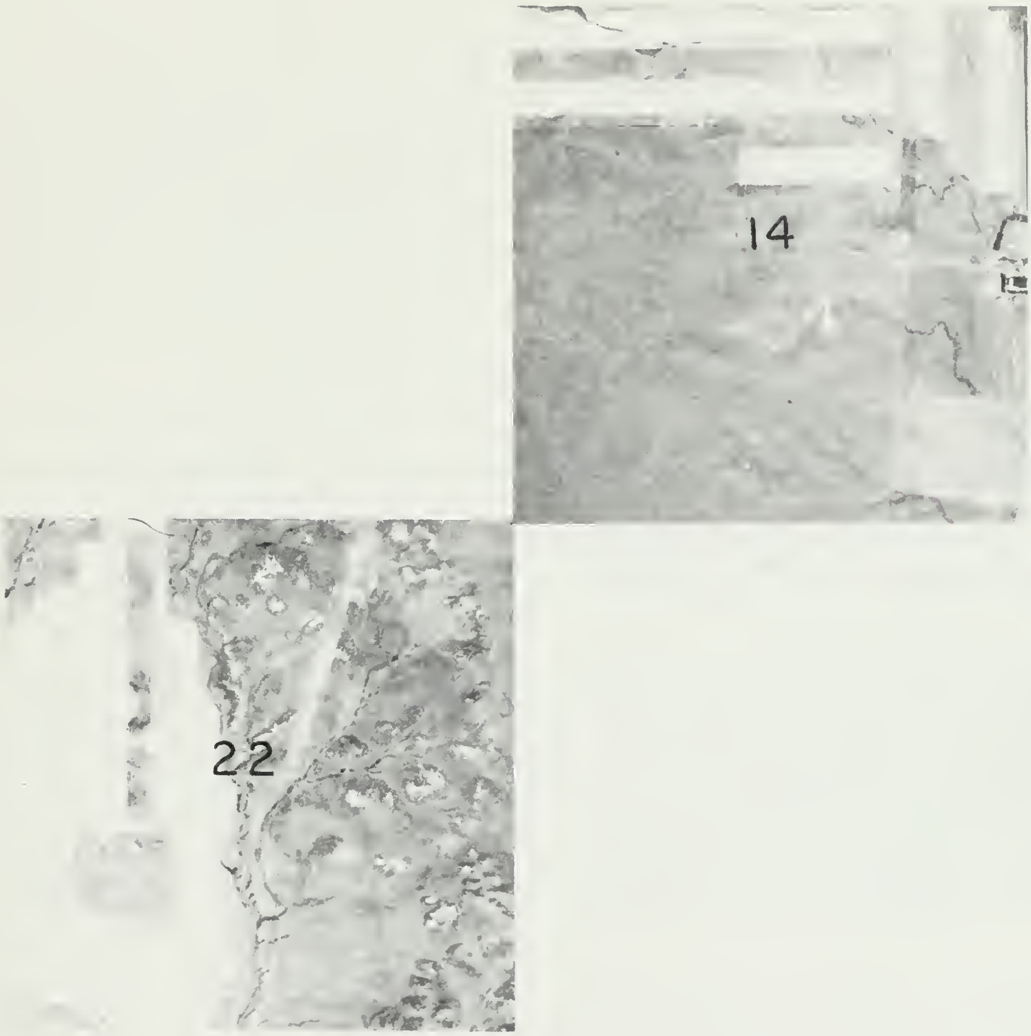
[1] See "Land Suitability Classification" section on page 21.

Photograph 1

Southwest Glendive Study Area
Sections 14 and 22, T. 15 N., R. 53 E.

1:24,000



Photograph 1 - Aerial View of Representative Sections Classified by the Bureau of Reclamation.

slightly sodic. These soils are used for dryfarm small grain production on gentle and moderate slopes; steeper slopes and narrow bottomlands are used for range. Table 4, Appendix C, is a "Point Site" soil profile representing this soil category.

The soils developing in residual sandstone, siltstone, or shale occupy ridges and moderate to very steep sideslopes on the remaining 50 percent of section 22. The sedimentary beds belong to the Tongue River Member of the Fort Union Formation.

The A horizon of these soils is usually dark colored, 2 to 6 inches thick, and very fine sandy loam to clay loam in texture. This horizon is absent on steep sideslopes and severely eroded ridges. A structural B horizon is usually lacking in these soils. The underlying C horizons are composed of weathered sedimentary beds of varying textures. The A horizon is nonsaline and nonsodic; the C horizons vary from nonsaline and nonsodic to strongly saline and slightly sodic, depending on the original composition of each sedimentary bed. These soils are used for dryfarm small grain production on ridges and moderate slopes; on steeper slopes they are used for range.

Upper Thirteenmile Creek Study Area

The east half of section 6 and all of section 8, T. 20 N., R. 53 E., were selected as representative for land classification by the USBR (see Photograph 2).

Soils developing in residual sandstone, siltstone, shale, or baked rock (Tongue River Member, Fort Union Formation) occur on about 55 percent of section 6 (E$^1/_2$) and approximately 30 percent of section 8. These soils occupy ridges and moderate to very steep sideslopes.

The A horizon of these soils is typically a silt loam, 2 to 4 inches thick (except Ap horizons - 6 inches). This horizon has been eroded off on steep sideslopes, exposing the parent strata. No structural B horizon is present. The underlying C horizons grade from medium-textured residuum into weathered sedimentary beds at an average depth of 18 inches. The A horizon is nonsaline and nonsodic; the C horizons and weathered sedimentary strata are nonsaline to moderately saline, depending on the original nature of the material; typically, they are nonsodic. Table 5, Appendix C, is a "Point Site" soil profile description representative of this soil category.

Soils forming in old alluvium cover about 35 percent of section 8 (northern portion) and a small piece near the east quarter corner of section 6 (E$^1/_2$). These soils occupy an undulating high terrace and a strongly sloping terrace edge.

The A horizon of these soils consists of 4 to 6 inches of loam or sandy loam on the high terrace and gravelly sandy loam on the terrace edge. The high terrace soils have a moderately well developed B horizon of loam texture which averages about 12 inches in thickness. No B horizon is present in the soils occupying the terrace edge. The C horizons on the high terrace grade from loamy alluvium into sand and gravel deposits at depths ranging from 24 to 50 inches. The sand and gravel deposits occur immediately below the A horizon on the terrace edge. These soils are nonsaline and nonsodic. The soils on the undulating high terrace are used for small grain production; soils on the steep terrace edge are used for range.

Soils developing in recent alluvium occur on about 45 percent of section 6 (E1/2) and 35 percent of section 8. These soils have developed in stream-laid deposits or local wash on gently to moderately sloping fans, footslopes, swales, and drainage bottoms.

The A horizon of these soils is commonly a dark colored loam which is 4 to 7 inches thick. A moderately developed B horizon of loam or clay loam, ranging in thickness from 10 to 20 inches, is common in these soils in section 8. No distinct B horizon was noted in these soils in section 6 (E1/2). The C horizons consist of medium-textured alluvium which overlies weathered silty or clayey shale at depths ranging from 3 to 4 feet on some fans and footslopes to over 10 feet in the drainage bottoms. The A and B horizons are usually nonsaline and nonsodic; locally, the C horizons and underlying shales are moderately to highly saline and slightly sodic. These soils are used for dryfarm small grain production or range. The "Point Site" soil profile description in Table 6, Appendix C, represents this soil category.

Woodson PRLA Study Area

Section 4, T. 20 N., R. 56 E., was selected for land classification by the USBR (see Photograph 3).

Soils developing in recent alluvium cover about 55 percent of this section. They occur on dissected alluvial fans and in the bottom of deeply-incised drainages.

The A horizon of these soils is typically a 2 to 5 inch thick loam or silt loam. A weakly or moderately developed B horizon is usually present; it ranges in thickness from 12 to 20 inches. The C horizons consist of stratified alluvium which overlies soft sedimentary beds at depths ranging from 2 feet on some fans to about 7 feet in the drainage bottoms. The A and B2 horizons are nonsaline and nonsodic; the B3 and C horizons, as well as the underlying sedimentary beds, are moderately to highly saline and slightly to highly sodic. These soils are used for range. Table 7, Appendix C, is a "Point Site' soil profile description representative of this soil category.

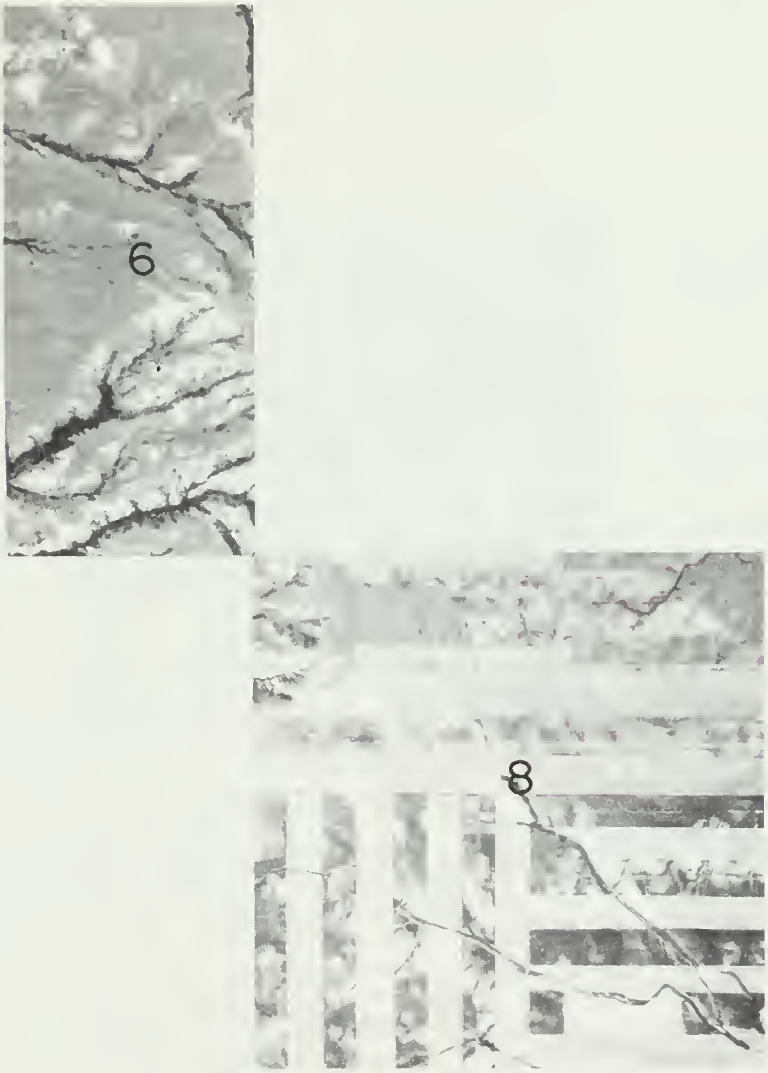
Soils forming in residual shale, siltstone, sandstone or baked rock (scoria) occur on about 40 percent of section 4. They occupy ridges and moderate to very steep sideslopes. The parent strata of these soils belong to the Tongue River Member of the Fort Union Formation. The A horizon of these soils is commonly a loam or silt loam, 1 to 3 inches thick. It is underlain by C horizons consisting of weathered residuum which grade into soft sedimentary beds. Textures of the C horizons are variable, depending on the nature of the parent materials. Depth to the sedimentary beds averages about 10 inches on ridges and moderate sideslopes; on steep slopes, the soil is eroded away as fast as it develops, leaving the parent strata exposed at the surface. The A and upper C horizons are usually nonsaline to moderately saline and nonsodic to slightly sodic. The sedimentary beds are often highly saline and moderately to highly sodic. These soils are used for range.

Soils forming in old alluvium occur on about 5 percent of this section. They occupy a thin, gently sloping high terrace (Butler Table) of the ancient Yellowstone River and a steeply sloping terrace edge (southwest part of section).

Photograph 2

Upper Thirteenmile Creek Study Area
Sections 6 (E½) and 8, T. 20 N., R. 53 E.

1:24,000



Photograph 2 - Aerial View of Representative Sections Classified by the Bureau of Reclamation.

Woodson PRLA Study Area
Section 4, T. 20 N., R. 46 E.

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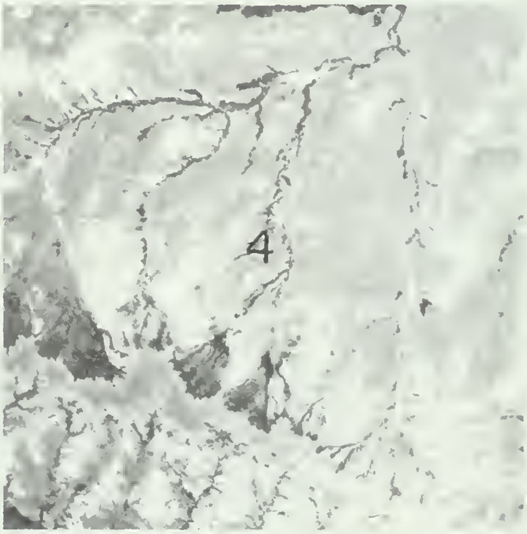

Photograph 3 - Aerial View of Representative Sections Classified by the Bureau of Reclamation.

The A horizon on the gently sloping terrace is a dark colored very fine sandy loam about 4 inches thick. It is underlain by a weakly developed B horizon of very fine sandy loam, which is about 10 inches thick. The C horizons grade from very fine sandy loam into medium and coarse sands at a depth of 5 feet. On the steeply sloping terrace edge, a thin A horizon of gravelly sandy loam overlies sand and gravel at a depth of 4 to 6 inches. These soils are nonsaline and nonsodic. They are used for range.

Land Suitability Classification

A semidetailed land suitability classification was made of representative sections in the Southwest Glendive, Upper Thirteenmile Creek, and Woodson PRLA Study Areas in order to evaluate and characterize the soil and overburden to 10 feet in depth as a source of material for revegetation if surface mining occurs. This classification provides data on the quantity and quality of material available for revegetation, as well as the ease with which this material can be stripped and stockpiled.

Land suitability specifications, shown on Table 8, were developed to establish classes for the specific use proposed, i.e., as a source of material for revegetation of surface-mined lands. Four land classes: 1, 2, 3, and 6 were developed. These correspond to classes used in the Bureau of Reclamation land classification system.

Factors included in the specifications for quality consideration were: texture, salinity, sodicity, percent gravel or coarser materials (> 3 inches) in the soil matrix, available water holding capacity, hydraulic conductivity, and erodibility. Quantity considerations were based primarily on the depth of the material. Topographic factors influencing the ease with which suitable material could be selectively stripped and stockpiled were also considered. These included steep, rough, or complex slopes and presence of hard bedrock exposures (outcrops).

Class 1 lands provide the most desirable and plentiful source of material for revegetation. An abundant supply of highly suitable material, which is easily stripped and stockpiled, will be available from this land class. In addition to having an adequate amount of suitable material for reclaiming the immediate area, Class 1 lands can provide borrow material for topdressing areas with insufficient suitable material. Class 2 lands contain an adequate supply of resurfacing material to revegetate the immediate area; however, this material is slightly less desirable in quality or somewhat more difficult to strip and stockpile than the material on Class 1 lands. Class 3 lands are similar to those in Class 2, except the deficiencies are more pronounced or a combination of deficiencies exists. Land in this class is marginally suitable for revegetation but, through utilization of good stripping and stockpiling procedures, the requirements for planting media can generally be met. Class 6 lands lack adequate quantities of suitable material to meet the needs for revegetation. If these lands are disturbed by surface mining, it will be necessary to borrow material from Class 1 or 2 lands or modify the material available for revegetation through leaching, addition of chemical amendments, etc.

Table 9 expands the preceding summary description of the land classes and describes the significant characteristics of the major land classes and subclasses.

The land suitability classification was accomplished using Bureau of Reclamation methods and procedures. Field mapping was done on aerial photographs with a scale of 1:12,000. Topographic drawings at a scale of 1:24,000 with 20-foot contour intervals were used for reference. An Abney hand level was used in the field to supplement the slope data on the topographic drawings.

Representative (Point Site) soil profiles typical of extensive areas of Class 1, 2, 3, and 6 lands were described, sampled, and analyzed in detail. Additional profiles were recorded in the heterogeneous soil areas to show variations within the delineated areas. This information was supplemented by nonrecorded profile examinations as required. Nonrecorded profiles are typically located in transitional areas between soil types to more accurately locate boundaries.

In the field appraisal, the top 16 inches of the soil profiles were exposed with a tile spade. A hand auger or hydraulic coring machine was then used to penetrate the soil/overburden to a depth of 10 feet unless hard bedrock was encountered. Soil structure, consistence, color, and other observable features of the exposed profile such as salinity, sodicity, and root distributions were recorded. Lime content was checked with dilute hydrochloric acid. Samples were collected from many of the exposed profiles. Evaluation of the soil/overburden material for hydraulic conductivity and available water holding capacity in relation to the reconstructed profile was a major consideration in the field evaluation. Using these basic evaluations, along with observations of other land features such as bedrock outcrops, slope, and landscape complexity, a land suitability class was tentatively assigned each delineated area while in the field. The suitability classes, when finalized, were recorded on land classification maps, Plates 26 through 28, Appendix C.

A laboratory was used in connection with the land suitability classification and screenable tests were performed on all samples. These tests included disturbed hydraulic conductivity, salinity, pH, 15-bar moisture retention, and settling volume. More detailed analyses were then made as required. Exhibit 1, Appendix C describes the screenable testing procedures used in the laboratory.

Complete analyses were performed on all samples from Point Site profiles representative of the major land class categories. The analyses listed in Exhibit 2, Appendix C, were performed as needed for proper soil and overburden evaluation.

Results of Land Suitability Classification

The results of the land suitability classification are presented on semidetailed drawings, Plates 26 through 28, Appendix C, which show the areal distribution of the various land classes, soil/overburden deficiencies, topographic deficiencies, profile notes of soil/overburden borings, and the results of selected laboratory analyses. This information is also summarized on Plates 29 through 34, Appendix C.

Plates 29 through 31, Appendix C, describe the location and depth of topsoiling material that is suitable for surface placement in reconstructed profiles. Plates 32 through 34, Appendix C, indicate the location and quantity of material that is suitable for subsurface replacement below the primary plant rooting zone.

Table 10 lists the acreage and percentage of each land class and subclass occurring in the representative sections classified by the USBR.

Table 8

LAND SUITABILITY SPECIFICATIONS - SURFACE MINE RECLAMATION
Suitability of Soil/Overburden for Revegetation of Surface-Mined Areas
BLM/BR Cooperative Program
Northeast Montana Investigations

United States
Dept. of the Interior
Bureau of Reclamation
April 1981

Soil and Overburden Characteristics	Basic Subclass	Symbols Information and Deficiencies	Class 1	Class 2	Class 3
SOILS AND/OR OVERBURDEN	s				
Textures			Fine sandy loams to clay loams	Sandy loam to silty clay loams	Loamy sand to clay
Coarse		v		Sandy loams sufficiently coarse to slightly reduce productivity, moisture retention and may increase erosiveness slightly.	Loamy sand in sufficient quantity to moderately reduce productivity, moisture retention, and may increase erosiveness moderately.
Fine		h		Profile should have sufficient material for topdressing, clayey type materials that are slowly permeable should be placed below 6" in the recontructed profile.	Profile should have sufficient material for topdressing; placement of clay in reconstructed profile-permeable: 10" plus; slowly permeable: 30" plus.
Depth		d	>36" of soil/overburden that is suitable for plant media.	>18" of soil/overburden that is suitable for plant media.	>10" of soil/overburden that is suitable for plant media.
Sodicity		a	SAR not to exceed 9.0 in fine textured materials but may be 20.0 with loamy sand textures. Values can be slightly higher if compensated by adequate residual gypsum.		
Salinity (ECe x 10^3)		s	Less than 4.	Less than 8 but should have 10" of material of less than 4 for surface.	Less than 12 but should have 10" of material of less than 4 for surface.
Available Water Holding Capacity		q	>1.5"/foot of soil.	>1.0"/foot of soil.	>0.75"/foot of soil.
Hydraulic Conductivity		p	Adequate to provide a well drained and aerated root zone and an infiltration rate adequate to prevent serious erosion.	Slightly restricted which may result in some restriction of drainage and aeration in the root zone and a reduced infiltration rate.	Restricted to the extent that internal drainage may limit choice of vegetation and require special practices to control erosion.
Gravel (soil profile)		k	Less than 10% by volume in soil mass.	Less than 20% by volume in soil mass.	Less than 50% by volume in soil mass.
Cobbly, Stony, Flaggy, or Clinkers (soil profile)		x	Less than 5% by volume in soil mass.	Less than 10% by volume in soil mass.	Less than 20% by volume in soil mass.
Weatherability[1]			Will break down readily upon exposure to the weather.	May require short period to break down upon exposure.	May require extended period to break down.
Erodibility			Susceptible to slight erosion.	Susceptible to moderate erosion.	Susceptible to severe erosion but can be controlled with proper management and selective placement.
TOPOGRAPHY[2]	t				
Slope		g	Permissible surface gradient 0-12% with smooth slopes.	Permissible surface gradient 0-20%.	Permissible surface gradient 0-35%.
Indurated Surface Sandstone or Baked Rock		r	None	1 to 5% of area.	5 to 20% of area.
Cover		c	Not applicable		
DRAINAGE	d		Because of anticipated land alterations by surface mining, present drainage conditions, except the hydraulic conductivity of the material, are not a factor in the classification.		
Class 6			Areas delineated in this class generally lack suitable material for stripping and stockpiling as surface material. One or a combination of the following deficiencies may result in the use of this class: (1) insufficient soil or overburden of suitable quality at or near the surface; (2) topography which prevents stripping, including excessive slopes; (3) rocklands with large amounts of indurated surface sandstone or baked rock; (4) toxic material (soil or overburden), at or near the surface. Reclamation of Class 6 lands will require that suitable plant growth material be borrowed from adjacent lands that have a surplus of good quality soil material or from suitable overburden strata. In certain cases, treatment or modification of the available material may increase its revegetative potential to an acceptable level.		

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[1] Applicable only to overburden material.
[2] Not applicable to overburden material.

Table 9 Description of Land Classes

Class Subclass	Soil/Overburden Characteristics	Land Features	Management Requirements
1	Land in this class has an average minimum depth of 36 inches of good or high quality soil/overburden that is suitable for plant media. Usually this material is medium textured soil that has formed in old or recent alluvial deposits. Soil aggregates have moderate to good stability and water enters the material readily. Internal permeability is moderate and adequate moisture is retained for plant growth. This rate of water movement provides adequate aeration of the plant root zone. Soil and overburden material in this class is nonsaline, nonsodic, and free of toxic contaminants. These lands usually have surplus high quality soil/overburden that is suitable for topdressing or subsurface placement. This material, when borrowed, will enhance productivity of other tracts.	The surface relief comprises nearly level to gently sloping terraces, fans, foot slopes, and bottomlands. Most of this land produces small grains. Topographic features will not hinder stripping and stockpiling. Selective stripping can be accomplished easily. Native mid and short grasses are the most common range species.	These materials will be slightly susceptible to wind and water erosion, but management practices such as vegetative mulch, mechanical roughing, or contour planting should be adequate control. For maximum use of soil in this land class, the upper 6-24 inches of surface material should be stripped and stockpiled separately from the subsoil and substratum.
2s	Land in this class has an average minimum depth of 18 inches of fair and good quality soil/overburden that is suitable for plant media. Usually this material is moderately coarse to moderately fine textured soil material that has developed in deep alluvial deposits or moderately deep residual material. Good quality overburden may be considered as part of the 18-inch requirement. Limitations other than depth include: clay rich layers, reduced moisture retention, restricted permeability, and layers that are saline and/or sodic. Soil agregates of these materials have fair to good stability and water enters the material at a moderate rate. The internal water movement is adequate to provide aeration of the primary plant root zone. Also, adequate moisture is retained for plant use. The material that is suitable for use at or near the surface is nonsaline and nonsodic and there is no indication of toxicity.	The surface relief comprises nearly level to gently sloping terraces, fans, and footslopes. This land is used for small grain production or native range. Topographic features will not hinder stripping and stockpiling can be accomplished easily.	Selection of suitable material for use at or near the surface will require a careful review of the field data. There is adequate topdressing material, but care must be exercised in selecting nonsaline, permeable materials for subsurface placement. Selective stripping and stockpiling to isolate subsurface material, followed by selective placement, is necessary for the best use of available material in this land class. With proper selection and placement, reclamation should not be difficult, and average management should enhance successful permanent revegetation.
2t	Land in this class has an average minimum depth of 36 inches of good and high quality soil/overburden that is suitable for plant media. Usually this material is medium textured soil that has formed in old or recent alluvial deposits. Soil aggregates have moderate to good stability and water enters the material readily. Internal permeability is moderate and adequate moisture is retained for plant growth. This rate of water movement provides adequate aeration of the plant root zone. Soil and overburden material in this class is nonsaline, nonsodic, and free of toxic contaminants. These lands usually have surplus high quality soil/overburden that is suitable for topdressing or subsurface placement. This material, when borrowed, will enhance productivity of other tracts.	The surfsce relief comprises undulating terraces and moderate sideslopes, fans, and footslopes. Selective stripping may be somewhat difficult, and some mixing of surface and subsurface material may occur.	These soils will be moderately susceptible to wind and water erosion, but managment practices such as vegetative mulch, mechanical roughing, or contour planting should be adequate control. For maximum use of soil in this land class, the upper 6-24 inches of surface material should be stripped and stockpiled separately from the subsoil and substratum.

Table 9 Description of Land Classes (cont'd)

Class Subclass	Soil/Overburden Characteristics	Land Features	Management Requirements
2st	The general description of soil/overburden characteristics of Class 2s applies to this class. The most common limitations are quantity of useable material, slow permeability, and/or moderate salinity and/or sodicity.	The surface relief comprises undulating terraces and moderate sideslopes, fans and footslopes. Selective stripping may be somewhat difficult, and some mixing of surface and subsurface material may occur.	A review of the field data to determine the the effect of unavoidable mixing of surface and subsurface material is needed to determine best stripping depths. This will also be a guide for placement in a reconstructed profile. The last paragraph describing management of Class 2s lands applies to this class also.
3s	Land in this class has an average minimum depth of 10 inches of fair to good quality soil/overburden that is suitable for plant media. Usually this material is largely medium to moderately fine textured soil that has formed in alluvium or residuum. The principal limiting factor is the quantity of nonsaline and nonsodic material for use at or near the surface. The subsoil and substratum often contain moderate to high levels of soluble salts; they are also slightly to moderately sodic. Land in this class retains a large quantity of available water. The infiltration rate and internal water movement are moderately slow.	The surface relief consists of nearly level terraces and gently sloping fans, footslopes, and swales. Selective stripping of desirable material should be easily accomplished. These lands are used for native range or small grain production.	For best use of the soil/overburden in this class, the surface material must be stripped and stockpiled, and the subsoil and substratum should be placed with the spoil material. Mechanical surface roughing will reduce runoff and help promote leaching of soluble salts. Mulching will also reduce runoff and erosion and enhance moisture conservation. Successful permanent revegetation can be accomplished, but above average planning and management will be required.
3t	Land in this class has an average of 36 inches of good and high quality soil/overburden that is suitable for plant media. Usually this material is medium textured soil that has formed in old or recent alluvial deposits. Surface material in this class is nonsaline, nonsodic, and moderately high in organic matter. There is no indication of toxic contaminants. Soil aggregates of these soils have moderate to good stability, allowing water to enter the surface layers readily. Internal permeability is moderate to moderately slow and adequate moisture is retained for plant growth. The rate of water movement provides adequate aeration of the plant root zone. These lands are a good source of quality soil/overburden that is suitable for topdressing or subsurface placement. This material, when borrowed, will enhance the productivity of other tracts.	The surface relief is comprised of steep, complex crests, sideslopes, and fans and narrow, tree-covered drainage bottoms. Selective stripping will be difficult. These lands are used for native range.	These soils will be moderately susceptible to wind and water erosion, but management practices such as vegetative mulching, mechanical roughing, or contour planting should provide adequate control. For maximum use of soil in this land class, the upper 6-24 inches of surface material should be stripped and stockpiled separately from the subsoil and substratum.
3st	Land in this class has an average minimum depth of 10 inches of fair to good quality soil/overburden that is suitable for plant media. Usually this material consists of medium to fine textured alluvium or weathered sedimentary beds (residuum). The major limitations are quantity of nonsaline/nonsodic material and clay-rich layers with slow permeability. There is adequate suitable material for reclamation to rangeland. Extensive borrowing of good quality material would be necessary to provide suitable rooting zones for small grain production.	The surface relief consists of steep, complex crests, sideslopes, fans and footslopes. Selective stripping of suitable material will be difficult. These soils are used for range and, to a minor extent, for small grain production where slopes permit.	Selective stripping, with emphasis on stripping local tracts of deep soil separately, should be considered. Similar surface treatment of reconstructed profiles as described in 3s should be followed.
6s	Land in this class has less than 10 inches average depth of fair and good quality soil/overburden that is suitable for plant media. These materials are typically clay-rich below the surface layer and often highly saline and/or sodium affected. One or a combination of the above factors make these materials unsuitable for plant media. Some small tracts with good quality soil/overburden occur in this class as inclusions.	This land class/subclass did not occur in the Southwest Glendive, Upper Thirteenmile Creek, or Woodson PRLA Study Areas.	

Table 9 Description of Land Classes (cont'd)

Class Subclass	Soil/Overburden Characteristics	Land Features	Management Requirements
6t	Land in this class has an average minimum depth of 36 inches of good and high quality soil/overburden that is suitable for plant media. Soils in this class have formed in recent alluvium. The surface layer is usually dark colored and moderately high in organic matter. Textures are commonly medium and moderately fine. These materials are nonsaline and nonsodic. Aggregate stability is moderate to good in these materials, and water readily infiltrates the surface. Internal permeability is moderate to moderately slow, and adequate moisture is retained for plant growth. The rate of water movement provides adequate aeration of the plant zone. Where accessible, the soils/overburden from this land class will provide good quality material suitable for topdressing or subsurface placement.	The surface relief comprises narrow, deeply incised drainage bottoms which are often tree covered. These drainages are commonly V-shaped with steep sideslopes. Stripping of suitable materials from these drainage bottoms will be extremely difficult. These lands are used for range; they also provide valuable cover for wildlife.	These soils may be highly susceptible to wind and water erosion. Management practices such as vegetative mulching, mechanical roughing, or contour planting will help retard soil erosion. Where accessible, the upper 6-24 inches of surface material should be stripped and stockpiled separately from the subsoil and substratum.
6st	Land in this class has less than 10 inches average depth of fair and good quality soil/overburden that is suitable for plant media. Soil materials are typically shallow over weathered sedimentary beds. Surface outcroppings of shale, sandstone, or baked rock (scoria) are common. On terrace edges, shallow soil materials occur over coarse sand and gravel deposits. The underlying overburden is highly variable in physical and chemical properties. It may be highly saline, highly sodic, slowly permeable, fine textured, or coarse textured. These limitations occur singly or in combination in most areas delineated as Class 6st. Small inclusions of deeper soils and permeable, nonsaline, and nonsodic overburden material occur infrequently within these delineated areas.	The surface relief consists of very steep sideslopes and narrow, severely eroded ridges. Active erosion has removed soil material on many ridges and sideslopes, leaving weathered shale, siltstone, sandstone, or baked rock (scoria) exposed at the surface. Steep terrace edges have less than 6 inches of soil material over coarse sand and gravel deposits. Selective stripping of suitable soil/overburden materials will be extremely difficult. These lands are used for range, where slopes permit.	Local inclusions with deeper soil or suitable overburden material, though small, should be selectively stripped. Mechanical roughing of the surface will increase infiltration and enhance leaching of soluble salts. Vegetative mulching, contour planting, and the use of stabilizing structures will aid in reducing erosion. Borrow material (Class 1 or 2 lands) will be required for successful permanent revegetation.

Table 10

Results of the Land Suitability Classification
Northeast Montana Investigations

Land Classes - Acreages

	1	2s	2t	2st	3s	3t	3st	6s	6t	6st	Total
Southwest Glendive Study Area - T. 15 N., R. 53 E.											
Section 14	324.7	129.9	0.0	101.8	33.6	13.9	36.1	0.0	0.0	0.0	640.0*
Section 22	189.5	96.7	21.7	104.0	33.8	20.4	123.3	0.0	0.0	50.6	640.0*
Total Acres	514.2	226.6	21.7	205.8	67.4	34.3	159.4	0.0	0.0	50.6	1280.0
Percent of Area	40.2	17.7	1.7	16.1	5.2	2.7	12.4	0.0	0.0	4.0	100.0
Upper Thirteenmile Creek Study Area - T. 20 N., R. 53 E.											
E1/2 Section 6	82.3	17.9	60.3	20.9	0.0	90.2	1.9	0.0	4.0	51.5	329.0*
Section 8	286.8	0.0	192.4	11.7	42.0	0.0	28.8	0.0	0.0	78.3	640.0*
Total Acres	369.1	17.9	252.7	32.6	42.0	90.2	30.7	0.0	4.0	129.8	969.0
Percent of Area	38.1	1.8	26.1	3.4	4.3	9.3	3.2	0.0	0.4	13.4	100.0
Woodson PKLA Study Area - T. 20 N., R. 56 E.											
Section 4	12.9	83.1	0.0	182.6	0.0	18.3	65.7	0.0	39.3	235.9	637.8*
Percent of Area	2.0	13.0	0.0	28.6	0.0	2.9	10.3	0.0	6.2	37.0	100.0

* Corresponds to GLO Survey Plat Acreages

The results in this table indicate that 96 percent of the two sections classified in the Southwest Glendive Study Area contains an adequate or surplus quantity of suitable material to restore the disturbed lands to a condition capable of supporting the present uses. This includes Classes 1, 2, and 3. The remaining 4 percent, designated as Class 6, consists mainly of shallow soils overlying either weathered sedimentary beds or sand and gravel deposits on eroded ridges or steep sideslopes.

In the Upper Thirteenmile Creek Study Area, 86.2 percent of the two sections classified contains adequate or surplus quantities of revegetative material (includes Classes 1, 2, and 3). The remaining 13.8 percent, placed in Class 6, is composed of shallow soils overlying sand and gravel deposits or soft shale on steep sideslopes in the eastern part of Section 6 and the northern portion of Section 8.

The representative section classified in the Woodson PRLA Study Area had 56.8 percent of the land placed in Classes 1, 2, or 3. The remaining 43.2 percent, designated as Class 6, consists mainly of very shallow soils occupying eroded ridges and very steep sideslopes ("badlands" in southern half of section) or deeply-incised, woody drainages which would severely limit stripping operations.

If surface mining occurs in any of these study areas, the steep sideslopes ("breaks") that presently exist in each area would undoubtedly be restored to a more gently sloping condition compatible with the overall reclaimed landscape. Surplus soil and/or good quality overburden could be borrowed from Class 1 or 2 lands to provide a deeper root zone and enhance permanent revegetation on these lands.

This land suitability classification provides baseline data for assessing reclamation potential. It does not, however, provide adequate detail for stripping and stockpiling procedures during the surface mining operation. Additional field borings and observations, supported by laboratory data, will be necessary to more accurately determine the quantity, quality, and location of available material to be stripped and stockpiled for use as a revegetative medium.

Soil and Overburden Suitability for Revegetation

Soil Mantle Suitability

Southwest Glendive

Plates 29 and 32, Appendix C, are maps showing the location and quantity of available topsoil and subsurface material in sections 14 and 22.

The soils developing in old alluvium, which occupy a high terrace covering almost all of section 14 and a small portion of section 22, should provide 24 to 36 inches (or more) of good quality topsoiling material for revegetation. This material, consisting of the A, B, and upper C horizons, is typically nonsaline, nonsodic, and permeable.

The A horizon, which averages 6 inches in thickness, could be selectively stripped as first lift material, followed by stripping of the B and upper C horizons in the second lift. The lower C horizons consist of sand and gravel deposits, weathered sedimentary beds, or loamy alluvium which, locally, contains moderate levels of soluble salts. Though abundant in quantity, these materials are fair to poor in quality for use as planting media; therefore, they should be placed at least 3 feet below the surface in reconstructed profiles.

Stripping operations on the gently sloping to undulating high terrace should be relatively easy.

The soils forming in recent alluvium on fans, footslopes, swales, and narrow drainage bottoms cover about 50 percent of section 22 and a very small portion of section 14. These soils should yield about 18 to 24 inches (or more) of good quality topsoiling material. This generally includes the A and upper C horizons of most of these soils. Since the A horizon is only 2 to 4 inches thick (except Ap - 6 inches), selective stripping of this horizon from the upper C horizons appears impractical. However, mixing of these horizons should not appreciably change the overall quality of the material.

The lower C horizons of these soils, consisting of loamy alluvium or weathered sedimentary beds, often contain moderate to very high levels of soluble salts. Locally, they are also heavy textured and slightly to moderately sodic. These undesirable properties should restrict placement of these materials to at least 3 feet below the surface in reconstructed profiles.

Stripping operations on the gentle and moderate slopes occupied by these soils should not be difficult, although the narrow drainage bottoms may pose some access problems for large machinery.

The soils developing in residual sandstone, siltstone, or shale, which occupy ridges and moderate to very steep sideslopes on about 50 percent of section 22, represent a limited source of revegetative material. Generally, less than 12 inches of fair or good quality soil material is present over the weathered sedimentary beds. This material, composed of a 2 to 6 inch thick A horizon and 6 to 12 inch thick upper C horizons, can probably be salvaged from some ridges and moderate sideslopes. Little or no soil material is available for stripping on the steeper sideslopes and severely eroded ridges.

The lower C horizons of these soils, consisting primarily of weathered shales, are often moderately to highly saline, slightly to moderately sodic, and heavy textured. These materials are of fair to poor quality for use as planting media; therefore, placement should be well below the plant rooting zone (2-3 feet) in reconstructed profiles.

Upper Thirteenmile Creek

Plates 30 and 33, Appendix C, are maps showing the location and quantity of topsoil and subsurface material available in sections 6($E\frac{1}{2}$) and 8.

Soils developing in recent alluvium on fans, footslopes, swales, and drainage bottoms occur on about 45 percent of section 6 ($E\frac{1}{2}$) and 35 percent of section 8. These soils should provide a minimum of 18 to 24 inches of topsoiling material that is medium textured, nonsaline, and nonsodic. This usually includes the A, B, and upper C horizons of these soils. Due to cultivation, most of these soils have an Ap horizon which averages 6 inches in thickness. This horizon could be selectively stripped in the first lift, followed by stripping of the B and good quality C horizons in the second lift.

The lower C horizons, consisting of stratified alluvium or soft sedimentary beds, are highly variable in texture and salt/sodium content. In most cases, however, they are of suitable quality for subsurface placement below the topsoil in reconstructed profiles. Where heavy textured or highly saline/sodic materials are encountered, they should be placed well below the plant rooting zone.

Since most slopes occupied by these soils are gentle or moderate, stripping operations should not be difficult, with the exception of some tree clearing in the drainages in section 6 (E1/2).

Soils forming in old alluvium occupy an undulating high terrace and steep terrace edge on about 35 percent of section 8 and a small part of section 6 (E1/2). Soils on the high terrace should yield about 24 to 36 inches of good quality topsoiling material. This material consists of the A, B, and upper C horizons, which are medium textured, nonsaline, and nonsodic.

The lower C horizons consist of sand and gravel deposits which are unsuitable for replacement in the root zone of reconstructed profiles. On the terrace edge, about 4 to 6 inches of gravelly sandy loam is available, but this would be virtually impossible to strip due to the steep, complex slope.

Stripping operations on the undulating high terrace should be easily accomplished.

About 55 percent of section 6 (E1/2) and 30 percent of section 8 are covered by residual soils developing in soft sedimentary beds (primarily shale). These soils occur on ridges and moderate to very steep sideslopes.

A limited quantity (average 12 inches) of fair to good quality topsoiling material is available from these soils on some ridges and moderate sideslopes. This material generally includes a thin A horizon and the upper C horizon(s). On steep slopes and severely eroded ridges, little or no suitable soil material is available for stripping.

Some of the underlying weathered sedimentary beds (lower C horizons) are of suitable quality for use as subsurface material immediately below the topsoil. However, many of the beds are heavy textured, moderately to highly saline, and/or moderately sodic. These materials are unsuitable for use as plant media; therefore, they should be selectively placed at least 3 feet below the surface in reconstructed profiles.

Stripping of suitable topsoil and subsurface material from these soils may be difficult due to slope limitations and landscape complexity, i.e., narrow ridges separated by steep slopes.

Woodson PRLA

Plates 31 and 34, Appendix C, are maps showing the location and quantity of available topsoil and subsurface material in section 4.

The soils developing in recent alluvium on dissected alluvial fans and in deeply incised drainage bottoms comprise about 55 percent of section 4. These soils should yield 12 to 18 inches (or more) of good quality topsoiling material. This material usually consists of the A and B2 horizons.

The underlying B3 and C horizons, consisting of loamy alluvium or soft sedimentary beds, often contain moderate to high levels of soluble salts. Locally, they are also moderately to highly sodic and/or heavy textured. These materials should be selectively placed below the plant rooting zone in reconstructed profiles.

Stripping operations should be easily accomplished on the gently to moderately sloping fans. Suitable material may be difficult to salvage in the drainage bottoms due to their narrowness, steep sideslopes, and tree/brush cover.

Soils developing in old alluvium occupy a thin, gently sloping high terrace and a steep terrace edge on approximately 5 percent of section 4. About 48 inches of good quality topsoil will be available from the high terrace soils. This material, which includes the A, B, and upper C horizons, consists of very fine sandy loam which is nonsaline, nonsodic, and permeable. Since the A horizon averages only 4 inches in thickness, it would appear impractical to selectively strip this horizon. The A and B horizons could be combined in the first lift without appreciably altering the quality of the material; the upper C horizons could than be salvaged in the second lift.

The lower C horizons are composed of sand and gravel deposits which should be placed well below the plant rooting zone. On the terrace edge, only 4 to 6 inches of gravelly sandy loam exists over the sand and gravel deposits. This material, though suitable in quality for root zone replacement, will be very difficult to strip due to slope limitations.

Stripping of available soil material on the high terrace should be easily accomplished.

The soils forming in residual sandstone, siltstone, shale, or baked rock (scoria) occur on about 40 percent of section 4. They occupy ridges and moderate to very steep sideslopes.

On some ridges and moderate sideslopes, these soils may yield 6 to 12 inches of fair to good quality topsoiling material. This material usually includes a thin A horizon and the upper C horizon(s). On the steep or very steep sideslopes (badlands) and severely eroded ridges, little or no suitable soil material is available.

Most of the underlying sedimentary strata (lower C horizons) are moderately to highly saline, moderately to highly sodic, and/or heavy textured. These materials are undesirable for root zone replacement; therefore, they should be placed at least 2 to 3 feet below the surface in reconstructed profiles wherever possible. Some of the parent strata which are medium textured and nonsaline/nonsodic or slightly saline/slightly sodic could be selectively stripped for subsurface placement below the topsoil in reconstructed profiles.

Overburden Suitability

Overburden samples from Bureau of Reclamation Drill Holes 81-101 through 81-109 (see Plates 16 through 24, Appendix B) were evaluated as to their suitability for use as a supplemental medium for revegetation. These drill holes were located as follows:

81-101	Woodson PRLA Study Area - Sec. 4, T. 20 N., R. 56 E.
81-102	Burns Creek Study Area - Sec. 30, T. 19 N., R. 56 E.
81-103	Burns Creek Study Area - Sec. 24, T. 19 N., R. 55 E.
81-104	Upper Thirteenmile Creek Study Area - Sec. 8, T. 20 N., R. 53 E.
81-105	Upper Thirteenmile Creek Study Area - Sec. 32, T. 21 N., R. 53 E.
81-106	Southwest Glendive Study Area - Sec. 14, T. 15 N., R. 53 E.
81-107	Southwest Glendive Study Area - Sec. 26, T. 15 N., R. 53 E.
81-108	Circle 2 Study Area - Sec. 26, T. 20 N., R. 49 E.
81-109	Circle 2 Study Area - Sec. 4, T. 20 N., R. 49 E.

Complete laboratory analyses, including selected trace element determinations, were performed on the samples by Bureau of Reclamation laboratories in Bismarck, North Dakota, and Boise, Idaho. The results of these analyses are included in Tables 11 through 19, Appendix C.

The suitability criteria listed in Table 20, Appendix C, were applied to the laboratory data in order to place the overburden materials into one of three categories: Suitable, Limited Suitability, or Unsuitable.

Table 21, Appendix C, presents the results of the overburden suitability evaluation. The results for each study area are discussed briefly below.

It should be recognized that this suitability evaluation is based on site-specific data collected at each drill hole. Any attempt to project the results within or between the study areas may be highly inaccurate due to wide variations in overburden characteristics. A much more detailed drilling program will be necessary prior to mining to more accurately determine the quantity and quality of the overburden materials.

Woodson PRLA Study Area - Drill Hole 81-101

Approximately 19 percent of the overburden materials were rated suitable for use as supplemental plant media, 69 percent were of limited suitability, and 12 percent were unsuitable.

The samples consisted of alluvium (0 to 28 feet) and interbedded sandstone, siltstone, or shale (28 to 131 feet) belonging to the Tongue River Member, Fort Union Formation.

Most of the samples were placed in the limited suitability category due to moderate salinity levels (EC = 4 - 8 mmhos/cm). These materials could be utilized on a local basis to supplement subsurface materials in reconstructed profiles, preferably, below 6 to 12 inches of good quality topsoil. The deepest sample obtained, a silty sandstone, was rated unsuitable due to an excessive level of exchangeable sodium. This material should be selectively placed well below the root zone in reconstructed profiles. Only one sample, a siltstone from 60.0 - 76.0 feet, was rated suitable for supplementing available topsoil and subsurface material.

Burns Creek - Drill Holes 81-102 and 81-103

About 48 percent of the samples from drill hole 81-102 were rated suitable, 30 percent were of limited suitability, and 22 percent were unsuitable. In drill hole 81-103, about 19 percent of the samples were classed as suitable, 52 percent were of limited suitability, and 29 percent were unsuitable.

The surface samples (10 to about 35 feet) from both drill holes consisted of alluvium (Flaxville Gravel); below this, the samples consisted of soft sandstone, siltstone, or shale of the Tongue River Member, Fort Union Formation.

The suitable samples from both drill holes consisted mainly of soft siltstones, silty sandstones, or silty shales which were medium textured, nonsaline, and nonsodic. If segregated during the mining operation, these good quality materials could be used to supplement available topsoil and/or subsurface material.

The major limiting factor for the samples classed as limited suitability or unsuitable was texture. The surface alluvium from both drill holes was rated unsuitable due to coarse texture. This material has a very low moisture holding capacity and low fertility, which makes it undesirable for root zone replacement. A number of shale and siltstone samples were moderately fine to fine textured, causing them to be placed in the limited suitability or unsuitable categories. If replaced at the surface, the slow to very slow permeability of these materials could create serious runoff and erosion conditions. The moderately fine textured materials could be utilized as supplemental subsurface material; the fine textured materials should be selectively placed below the root zone in reconstructed profiles.

Upper Thirteenmile Creek - Drill Holes 81-104 and 81-105

In drill hole 81-104, approximately 37 percent of the overburden materials were classified as suitable for use as supplemental plant media, 37 percent were of limited suitability, and 26 percent were unsuitable. About 54 percent of the samples from drill hole 81-105 were rated suitable and 46 percent were of limited suitability. No samples from this drill hole were determined to be unsuitable.

The samples consisted primarily of soft siltstones, shales, or sandstones belonging to the Tongue River Member of the Fort Union Formation, although the surface sample (10-14 feet) from drill hole 81-105 consisted of alluvium.

The suitable materials consisted of silty sandstones or silty shales which were medium textured, nonsaline, and nonsodic. These materials could provide a valuable supplement to existing subsurface materials. On lands lacking adequate quantities of suitable soil material, these materials could also be utilized for topsoil.

About half of the samples were moderately fine textured and/or moderately saline, causing them to be placed in the limited suitability category. Though undesirable for topsoil, these materials could be salvaged to supplement existing subsurface materials.

Only three samples (all shales in 81-104) were classified as unsuitable. Two of these samples were fine textured and the remaining sample contained a high level of exchangeable sodium. These materials should be placed well below the root zone.

Three shale samples from these drill holes contained a moderately high level of nickel (3-5 ppm). Under the present alkaline condition of the overburden materials, the availability of this element to plants is reduced; therefore, the potential for toxicity appears low.

Southwest Glendive - Drill Holes 81-106 and 81-107

About 64 percent of the overburden materials from drill hole 81-106 were rated suitable for use as supplemental revegetative media and 36 percent were unsuitable. None of the materials were placed in the limited suitability category. Only three samples were obtained from drill hole 81-107 due to poor core recovery. Of these, two were of limited suitability and one was unsuitable.

Stratified alluvium (Cartwright Gravel) comprised the first 78 and 92.5 feet, respectively, in drill holes 81-106 and 81-107. The suitability of these materials varies with texture, i.e., the silty or fine sandy materials are suitable or of limited suitability for use as supplemental plant media and the coarse sandy and/or gravelly materials are unsuitable. The suitable/limited suitability materials could be selectively stripped for replacement in the root zone of reconstructed profiles.

Below the alluvium, silty or sandy shale samples (Tongue River Member, Fort Union Formation) were obtained from above and immediately below the major coal seam.

One shale sample from drill hole 81-106 was rated suitable for use as revegetative material and two were categorized as unsuitable. The suitable material, a silty shale overlying the coal seam, was nonsaline, nonsodic, and medium textured. The unsuitable materials, located immediately below the coal seam, contained high levels of exchangeable sodium. In addition, these samples also contained moderately high levels of nickel. However, the existing alkaline nature of these overburden materials will limit the availability of this element and reduce the potential for phytoxicity. The unsuitable materials should be replaced well below the root zone in reconstructed profiles.

Both silty shale samples from drill hole 81-107 were determined to be of limited suitability due to their moderately fine texture. Also, a moderately high nickel content occurred in the deepest sample (underlying the coal seam).

As previously noted, the existing alkaline condition of this overburden material will limit the availability of this element, reducing its potential toxic effects to plants. Though undesirable for topsoil, these overburden materials could be salvaged to supplement available subsurface materials.

Circle 2 - Drill Holes 81-108 and 81-109

None of the overburden samples from these two drill holes were rated suitable for use as supplemental plant media. In drill hole 81-108, about 40 percent of the materials were of limited suitability and 60 percent were unsuitable. Approximately 21 percent of the materials in drill hole 81-109 were of limited suitability and 79 percent were unsuitable.

All samples from these drill holes consisted of soft shales, siltstones, or sandstones belonging to the Tongue River Member, Fort Union Formation.

The materials classified as limited suitability were restricted by moderately fine texture, moderate salinity, and in the uppermost siltstone/shale sample from drill hole 81-108, a moderately high content of manganese. The availability of this element to plants will be limited by the alkaline condition of the overburden; thus, the potential for manganese toxicity appears low. The limited suitability materials could be salvaged to supplement available subsurface materials in reconstructed profiles.

A significant percentage of the overburden materials from these two drill holes were determined to be unsuitable for use as revegetative media. The major limiting factor of these materials was high exchangeable sodium. In additon, some of the samples were fine textured or moderately saline. These materials should be selectively placed well below the plant rooting zone in reconstructed profiles.

GREENHOUSE EVALUATION OF SOIL AND OVERBURDEN MATERIALS

Introduction

The data in this section was provided by E&A Environmental Consultants, Inc., Stoughton, Massachusetts, under Bureau of Reclamation Contract Number 1-07-DV-00124.

This report presents the greenhouse data for 26 soil and overburden samples obtained from the Southwest Glendive, Upper Thirteenmile Creek, and Woodson PRLA Study Areas in northeastern Montana. These samples were obtained from 5 USBR "Point Site" soil profiles described in Tables 3 through 7, Appendix C. Table 22 identifies the greenhouse samples as to study area, Point Site (Hole) number, depth, and horizon(s) obtained from.

Greenhouse Procedures

The soil or overburden materials were placed in 10-inch pots where possible. Smaller 8-inch or 6-inch pots were used when low quantities of the materials were available. Whenever possible, replicates were run.

Each pot was packed with a uniform amount of soil or overburden material. Prior to seeding, each sample received nitrogen and phosphorus fertilizer at a rate of 60 lbs./acre N as ammonium nitrate and 80 lbs./acre P as triple phosphate. In some cases, nitrogen deficiencies occurred during the growth cycle, necessitating the addition of a complete fertilizer.

Initially, the pots were seeded with 35 seeds per pot of Barley Var. Steptoe1/. However, poor germination due to poor surface conditions and excessive surface drying necessitated a higher seeding rate. The pots were reseeded with 100 seeds and covered to maintain humid conditions favorable for germination. The pots received limited watering, about 3 times per week with approximately 100 ml, in order to avoid excessive leaching of salts.

The plants were harvested after a 60-day growth cycle, and dry weights were recorded.

Laboratory Procedures - Soil and Overburden

The following analyses were performed by the Bureau of Reclamation Regional Soil and Water Laboratory in Boise, Idaho, according to the procedures outlined in Exhibit 2, Appendix C: particle size analysis, cation-exchange-capacity, saturation percentage, salinity (saturation extract), exchangeable sodium percentage, sodium adsorption ratio, and soluble calcium and magnesium.

Plant - available phosphorus (P), potassium (K), zinc (Zn), iron (Fe), copper (Cu), and manganese (Mn) were analyzed by E&A Environmental Consultants, Inc., according to the following procedure:

The extracting solution was a 10 percent solution of sodium acetate in 3 percent acetic acid of a pH of 4.8. Five grams of sample which had been passed through

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1/ This variety was obtained from the USDA High Plains Grassland Research Station in Cheyenne, Wyoming.

a 2 mm (No. 10) screen were extracted with 15 ml of the extracting solution. The extractant was then shaken for 20 minutes using a wrist action shaker at 150 oscillations per minute. After one minute of settling, the solution was filtered through a Whitman No. 2 filter. Ten ml of the filtrate was analyzed using an inductively coupled argon plasma spectrophotometer (ICAP).

Plant - available cadmium (Cd), nickel (Ni), and lead (b) were also analyzed by E&A Environmental Consultants, Inc., using diethylenetriaminepentaacetic acid (DTPA) as the extracting solution. The extracts were then analyzed using ICAP for cadmium and lead and atomic absorption spectrophotometry for nickel.

Plant Analysis Procedures

The fresh plant samples were oven-dried at 60°C for a minimum of 48 hours. Approximately 2 grams of the dried sample was then ground in a Wiley Mill through a 20 mesh screen.

One-half gram of the ground sample was placed in a porcelain crucible and ashed in a muffle furnace for 12 hours at 500°C. Five milliliters of concentrated hydrochloric acid was added to the ashed sample. After 20 minutes, the sample was washed into a 25 ml volumetric flask and brought up to volume with 1N HCl.

The concentrations of the following 15 elements were determined with the ICAP emission spectrophotometer, Jarrell-Ash Model 955:

Macronutrients - phosphorus, potassium, calcium, magnesium
Micronutrients - zinc, boron, manganese, molybdenum, iron, copper, sodium
Heavy metals - cadmium, lead, arsenic, aluminum

Preplant Analysis - Soil and Overburden

Table 23, Appendix D, lists the miscellaneous preplant data supplied by the Bureau of Reclamation. Tables 24 and 25, Appendix D, respectively, show the plant - available and total analysis levels of various elements analyzed by E&A Environmental Consultants, Inc.

As shown in Table 23, Appendix D, all of the soil or overburden samples were medium or moderately fine textured. A few samples, i.e., G-161-163, contained a high percentage of silt (>80 percent). These materials would be highly susceptible to wind erosion if replaced as topsoil on reclaimed lands; therefore, they should be selectively placed beneath 6 to 12 inches (or more) of topsoil in reconstructed profiles.

Samples obtained from the Southwest Glendive and Upper Thirteenmile Creek Study Areas were nonsaline (A, B, and upper C horizons) or slightly saline (lower C horizons). The slightly saline materials are undesirable as a germination medium (topsoil), but could be utilized as subsurface material in the plant rooting zone. All of the samples obtained from these two study areas were nonsodic.

The A and B horizons (G-213 and G-214) in the soil profile from the Woodson PRLA Study Area were nonsaline and slightly saline, respectively. They were both nonsodic. The C horizons from this profile, however, were both highly saline

Identification of Greenhouse Samples

Sample	Study Area	USBR Point Site No.	Horizon/Depth
G-159	Upper Thirteenmile Creek	6	A1 & C1/0-8"
G-160	" " "	6	C2k/8-27"
G-161	" " "	6	C3r/27-52"
G-162	" " "	6	C3r/52-76"
G-163	" " "	6	C3r/76-100"
G-164	" " "	6	C4r/100-120"
G-165	" " "	9	Ap & B2/0-17"
G-166	" " "	9	B3k & C1k/17-36"
G-167	" " "	9	C1k/36-54"
G-168	" " "	9	C1k & C2/54-78"
G-169	" " "	9	C3r/78-108"
G-170	Southwest Glendive	11	Ap & B2/0-11"
G-171	" "	11	B3k & C1k/11-24"
G-172	" "	11	C1k/24-38"
G-173	" "	11	C2/38-60"
G-174	" "	11	C2/60-84"
G-175	" "	11	C2/84-120"
G-176	" "	10	Ap & B2/0-13"
G-177	" "	10	B3k & C1k/13-33"
G-178	" "	10	C2/33-56"
G-213	Woodson PRLA	8	A1/0-5"
G-214	" "	8	B2 & B3/5-24"
G-215	" "	8	C1/24-42"
G-216	" "	8	C1/42-58"
G-217	" "	8	C2/58-90"
G-218	" "	8	C2/90-120"

and highly sodic. These horizons would create deleterious effects on plant germination and development if they were replaced in the root zone of a reconstructed profile; therefore, they should be selectively placed beneath 2 to 3 feet of nonsaline/nonsodic material.

All of the plant - available levels (Table 24, Appendix D) were within the normal ranges found in soils (see Table 26, Appendix D). With the exception of arsenic, all other total analysis levels (Table 25, Appendix D) were also within the normal ranges.

Statistical analyses were performed on the preplant data; the results are presented in Tables 27, 28, and 29, Appendix D.

Postharvest Analysis - Soil and Overburden

Postharvest plant - available and total analysis, determined by E&A Environmental Consultants, Inc., are listed in Tables 30 and 31, Appendix D. Statistical analyses performed on these data are included in Tables 32 and 33, Appendix D.

Arsenic levels (total analysis) were again high, correlating with the preplant analysis data. All other postharvest plant - available and total analysis levels were within the normal ranges found in soils.

Correlation of Plant Dry Weights and Preplant and Postharvest Soil/Overburden Analysis

The correlation coefficients for dry weights of the plants versus the preplant and postharvest soil/overburden analyses are shown in Tables 34, 35, and 36, Appendix D. All of the "R" values (correlation coefficients) were low, indicating no significant trends.

Plant Tissue Analysis

The data obtained from the plant tissue analysis are listed in Table 37, Appendix D. Statistical analyses performed on these data are included in Tables 38 and 39, Appendix D.

With the exception of lead, the coefficient of variation was low (Table 38). Cadmium showed the best correlation with plant dry weight, with an "R" value of 0.472 (Table 39). Boron may have been sufficiently high in some plants to cause a reduction in productivity, i.e., sample G-178 contained 46.69 ppm B and produced only 1.9 grams of dry plant matter.

Summary of Findings

1. All of the soil or overburden samples were medium or moderately fine textured. A few of the samples (obtained from C horizons) contained a high percentage of silt (>80 percent), making them undesirable for surface replacement in reconstructed profiles. These materials would be highly susceptible to wind erosion.

2. Samples from the Southwest Glendive and Upper Thirteenmile Creek Study Areas were nonsaline (A and B horizons) or slightly saline (C horizons). They were all nonsodic. The A and B horizons in the soil profile from the Woodson

PRLA Study Area were nonsaline and slightly saline, respectively. The lower C horizons, however, were highly saline and highly sodic. The slightly saline materials, though undesirable as a germination medium (topsoil), could be utilized as subsurface material. The highly saline/sodic materials could severely restrict plant germination and development if they are replaced in the root zone; they should be selectively placed below 2 to 3 feet of nonsaline/nonsodic material wherever possible.

3. Arsenic levels (total analysis) were high in both the preplant and postharvest analysis of the soil and overburden materials. However, the plant tissue analysis showed low uptake of this element, indicating no apparent phytotoxic effects, at least to this test species (Barley Var. Steptoe).

4. Boron levels (total analysis) were within the normal range for soils in both the preplant and postharvest analysis of the soil and ovrburden materials. However, some of the plants contained a relatively high level of this element, possibly in sufficient quantity to reduce productivity.

5. Overall, the correlation coefficients ("R" values) for plant dry weights versus both the preplant and postharvest analyses of the soil and overburden were low, indicating no significant trends. Cadmium (in the plant tissue) had the best correlation with plant dry weight, with an "R" value of 0.472.

The greenhouse serves as a valuable tool for stratifying overburden materials as to their relative productivity. This type of evaluation appears to be a very useful part of a screenable testing program. The combined greenhouse and laboratory data are keys to identifying the nature and extent of further evaluations that are necessary to accurately predict revegetation potential of various soils and overburden.

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APPENDIX A

ENGLISH TO METRIC CONVERSIONS

ENGLISH TO METRIC (SI) CONVERSIONS

Multiply English Units	By	
Inches	25.40	Millimeters (mm)
Feet	0.3048	Meters (m)
Miles	1.609	Kilometers (km)
Acres	0.4047	Hectares (ha)
	0.004047	Square Kilometers (km^2)
Square Miles	2.590	Square Kilometers (km^2)
Acre-Feet	0.001233	Cubic Hectometers (hm^3)
Cubic Yard	0.7646	Cubic Meter (m^3)
Feet Per Mile	0.1894	Meters Per Kilometer (m/km)
Btu Per Pound	0.556	Kilogram Calories Per Kilogram (kcal/kg)
Pounds	453.60	Grams (g)

Convert Degrees Fahrenheit to Degrees Celsius: °C = 5/9(°F - 32)

APPENDIX B

GEOLOGY

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE Woodson PRLA PROJECT EMRIA STATE Montana
HOLE NO. DH81-101 LOCATION 300' N. of S.E. Corner, Sec. 4. COORDS. N.T. 20 N., R. 56 E. GROUND ELEV. 2450'± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 1-13-81 FINISHED 1-16-81 DEPTH OF OVERBURDEN ----- TOTAL DEPTH 147.0' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Drill
Failing 1500 truck-mounted.
Driller
R.V. Shaw
Method
Bx drive 0-10'. 3-7/8" rock bit 10-11'. Hq wireline core 11-28.5'. 3-7/8" rock bit 28.5-30'. Hq wireline core 30-147'. Water and Revert used as drill fluid. Water losses noted below:

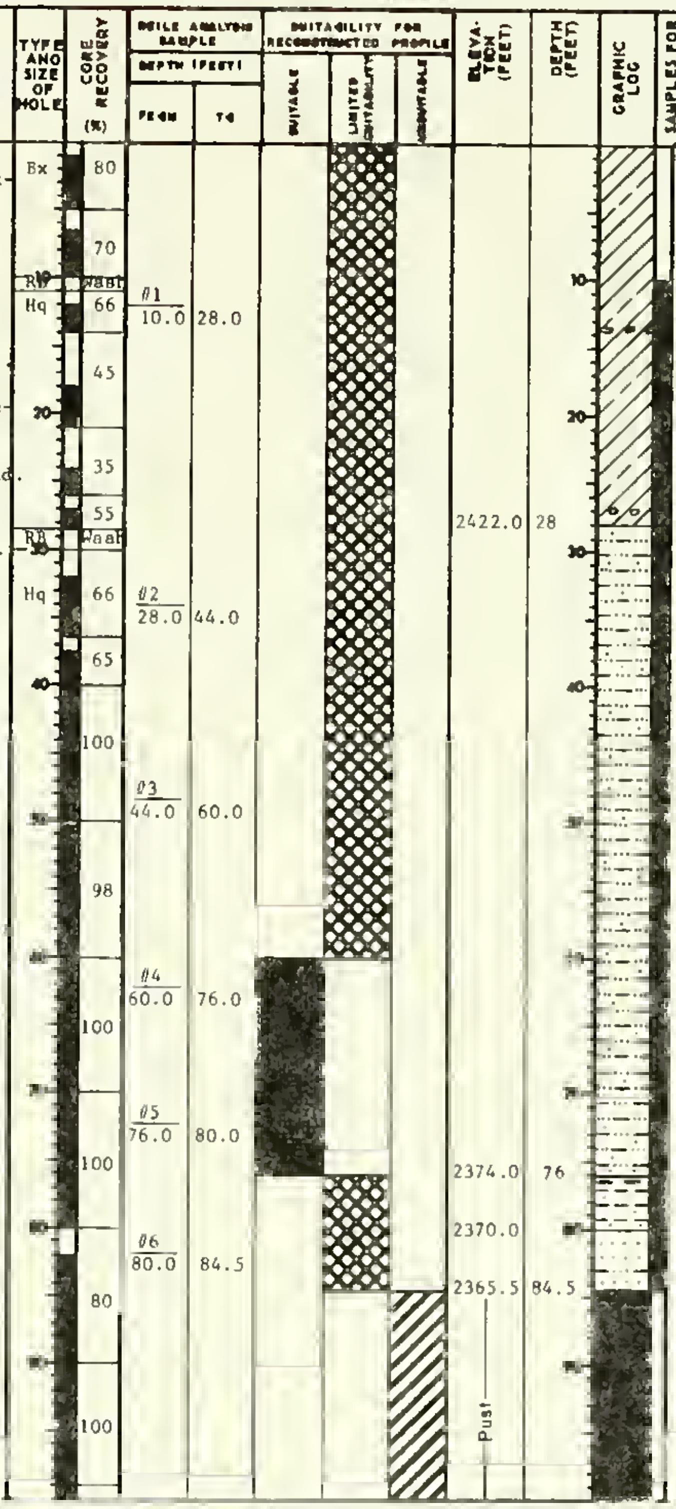
Depth	% Loss
14.5'	60-80
30-90'	10-20
91'	100

Casing Record
Set Hw casing to 32' on 1-13-81 to prevent water loss and caving.
Progress Record

Depth	Date
0-30'	1-13-81
30-90'	1-14-81
90-141'	1-15-81
141-147'	1-16-81

Hole Completion
Pulled all casing and backfilled hole 1-16-81.
Water Levels
Not stabilized.

Depth	Date
Dry	1-14-81
121'	1-16-81



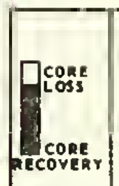
Sample	From	To
#1	10.0	28.0
#2	28.0	44.0
#3	44.0	60.0
#4	60.0	76.0
#5	76.0	80.0
#6	80.0	84.5

Elevation (feet)	Depth (feet)
2422.0	28
2374.0	76
2370.0	
2365.5	84.5

CLASSIFICATION AND PHYSICAL CONDITION

HOLOCENE
0-28.0' SANDY SILT (COLLUVIUM?): approx. 90 percent nonplastic to slightly plastic fines; 10 percent very fine sand; tan; dry to moist; loose to crumbly; scattered roots to 14'; strong HCl reaction. (ML) to (ML-CL)
13.8-14.0' Gravel: subrounded; to 2" diameter; probably washed from a high terrace.
26.5-27.5' Gravel: similar to above.
PALEOCENE-TONGUE RIVER MEMBER-FORT UNION FORMATION
28.0-76.0' SANDY SILTSTONE: tan to grayish tan near bottom; yellowish brown oxidized zones; soft; crumbly; some slightly clayey zones; strong HCl reaction; bedding not discernible; core lengths to 1'.
Note: Drill hole located in swale below a saddle. The bedrock-soil contact could not be readily determined, so the break was made just below the lowest gravel zone.
76.0-80.0' SANDY SHALE: light gray; moist; very soft-resembles clay; crumbles easily; air slakes; silty; scattered small gypsum crystals; weak to moderate HCl reaction; bedding not discernible; core lengths to 15".
76.5-76.8' Carbonaceous zone with some coal.
80.0-84.5' SILTY SANDSTONE: light gray; moist; uncemented; loose to crumbly; extremely fine grained; scattered pyrite nodules; moderate HCl reaction; bedding not discernible; core lengths to 10".
84.5-121.2' COAL: black; moist; brittle.
112.5-113.0' Carbonaceous shale.
121.2-131.0' SILTY SANDSTONE: light gray; moist; uncemented; crumbles easily; extremely fine grained; moderate HCl reaction; bedding not discernible; core lengths to 8".
123.0-123.8' Carbonaceous shale with thin coal lenses.
131.0-147.0' SILTY SHALE: light gray; moist; soft; core edges break easily; sandy; slight air slaking; some crumbly sandstone lenses; moderate HCl reaction; bedding nearly horizontal; core lengths to 3'; a few gastropod fossils.
133.0-133.4' Coal.

EXPLANATION



Type of hole	D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed	P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series)	Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series)	Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series)	Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series)	Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Woodson PRLA PROJECT EMRIA STATE Montana SHEET 1 OF 2 HOLE NO. DH81-101

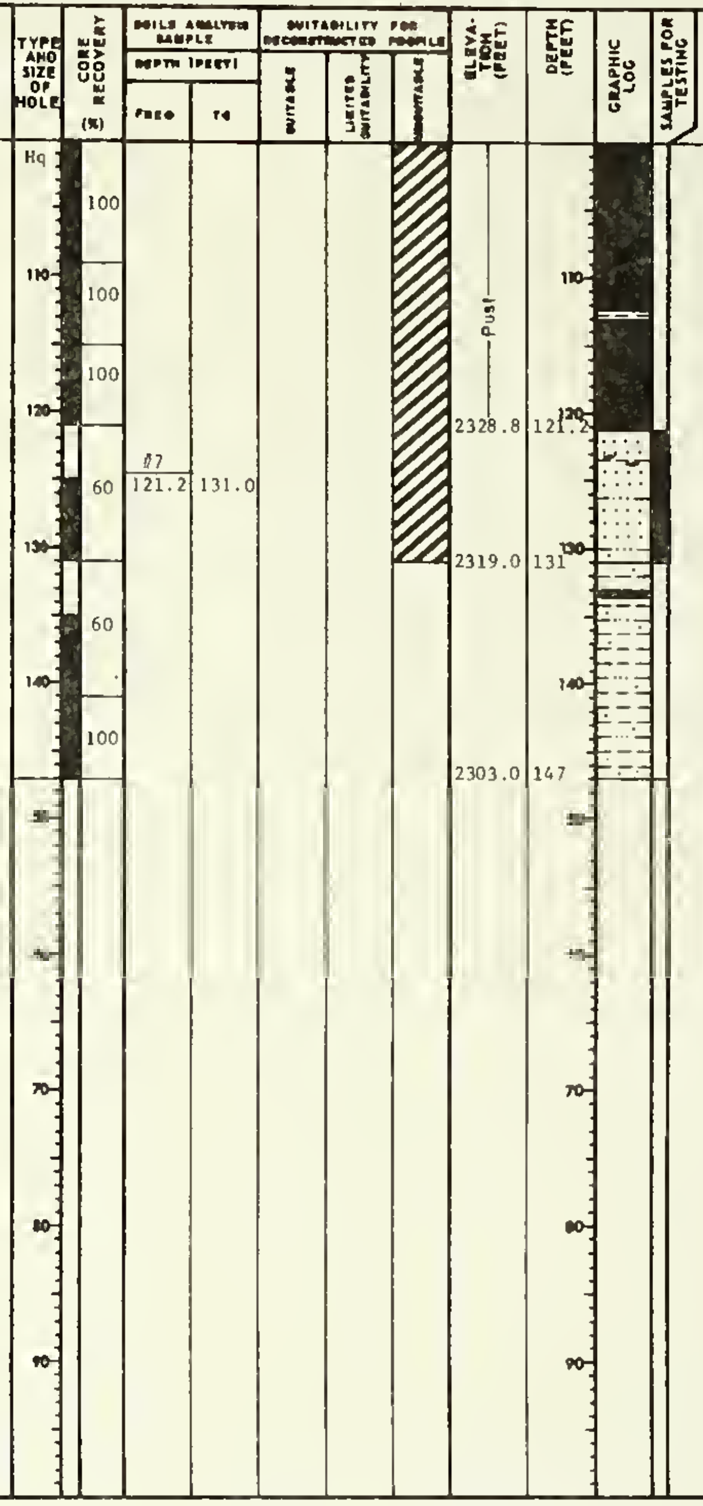
GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

FEATURE Woodson PRLA PROJECT EMRIA STATE Montana
HOLE NO. DH81-101 LOCATION 300' N. of SE Corner, Sec. 4. COORDS. N.T. 20 N., R. 56 E. GROUND ELEV. 2450'± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 1-13-81 FINISHED 1-16-81 DEPTH OF OVERBURDEN ----- TOTAL DEPTH 147.0' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

CLASSIFICATION AND PHYSICAL CONDITION



Sample	From	To
#7	121.2	131.0

Elevation (feet)	Depth (feet)
2328.8	121.2
2319.0	131
2303.0	147

EXPLANATION

Type of hole	D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed	P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series)	Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series)	Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series)	Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series)	Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Woodson PRLA PROJECT EMRIA STATE Montana SHEET 2 OF 2 HOLE NO. DH81-101

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE AND POTENTIAL RECLAMATION EVALUATION

NORTHEAST MONTANA INVESTIGATIONS
WOODSON PRLA STUDY AREA-MONTANA

GEOLOGIC LOG OF DH 81-101

GEOLOGY L. PARISH FIELD APPROVAL
DRAWN TECHNICAL APPROVAL
CHECKED APPROVED

BILLINGS, MONTANA MAY 1983 1305-600-358

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

FEATURE Burns Creek PROJECT EMRIA STATE Montana
HOLE NO. DH81-102 LOCATION 2650'E. & 1950'S. of N.W. Corner Sec. 30, T. 19 N., R. 56 E. GROUND ELEV. 2725'± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 1-19-81 FINISHED 1-29-81 DEPTH OF OVERBURDEN -------- TOTAL DEPTH 270.0' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Drill
Failing 1500 truck-mounted.
Driller
R.V. Shaw
Method
Bx drive 0-15'. Enlarged with 6" rock bit to 20'. Bx drive 20-24'. 3-7/8" rock bit 24-29'. Bx drive 29-32.5'. 3-7/8" rock bit 32.5-36.4'. Hq wireline core 36.4-270.0'. Water and Revert used as drill fluid. Water losses noted below:

Depth	% Loss
5-33.6'	100
124-214'	15
214-220'	80
220-270'	80

Casing Record
Set Hw casing to prevent caving and water loss.

Depth	Date
0-20-5'	1-19-81
20.5-35.5'	1-20-81

Pulled all casing 1/19/81.

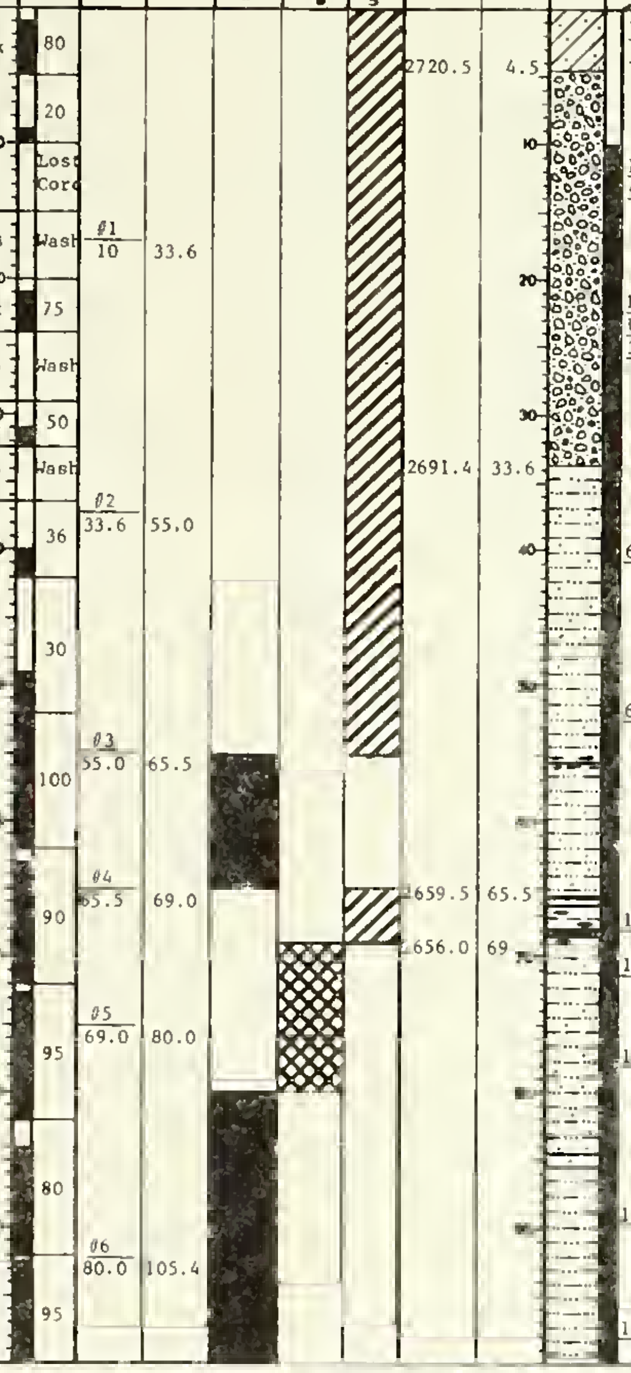
Progress Record

Depth	Date
0-20'	1/19/81
20-62'	1/20/81
62-132'	1/21/81
132-190'	1/22/81
190-220'	1/27/81
220-270'	1/28/81

Hole Completion
Pulled casing 1/29/81. Backfilled hole.

Water Levels
Taken while drilling in progress. Were not stabilized.

Depth	Date
Dry	1/20/81
13.7'	1/21/81
38.7'	1/22/81
36'	1/27/81
[illegible]	[illegible]
191'	1/29/81



Type and size of hole	Core recovery (%)
Bx	80
	20
	Lost Core
RB	Wash
Bx	75
RB	Wash
Bx	50
RB	Wash
Hq	36
	30
	100
	90
	95
	80
	95

Soils analysis sample	Depth (feet) from	to
#1	10	33.6
#2	33.6	55.0
#3	55.0	65.5
#4	65.5	69.0
#5	69.0	80.0
#6	80.0	105.4

Elevation (feet)	Depth (feet)
2720.5	4.5
2691.4	33.6
2659.5	65.5
2656.0	69

CLASSIFICATION AND PHYSICAL CONDITION

HOLOCENE

0-4.5' SANDY SILT (COLLUVIUM?): approx. 80% nonplastic fines; 20% very fine sand; tan; moist; loose to crumbly; some caliche near bottom; strong HCl reaction. (ML)

LATE TERTIARY - FLAXVILLE GRAVEL

4.5-33.6' GRAVEL: approx. 55% subangular to subgrounded gravel to 2"; 40% fine to coarse sand; 5% nonplastic fines; brown; moist; loose; no HCl reaction. (GP)

PALEOCENE - TONGUE RIVER MEMBER - FORT UNION FORMATION

33.6-65.5' SANDY SILTSTONE: yellowish tan; moist; soft; crumbles easily; contains slightly clayey zones; very fine grained sand; oxidized; some air slaking; moderate HCl reaction; bedding not discernible; core lengths to 2'.
54.0' Joint dips 60°.
55.5-55.8' Carbonaceous zone with thin coal lenses.

65.5-69.0' CARBONACEOUS SHALE: medium to dark gray; moist; soft; cuts easily with knife; sandy; weak HCl reaction; bedding nearly horizontal; core lengths to 10".
Shaley Coal: 65.5-65.7'; 66.2-66.3'; 67.9-68.5'.

69.0-105.4' CLAYEY SILTSTONE: light gray; moist; cuts easily; slightly sandy; occasional pyrite nodules; moderate to strong HCl reaction; bedding nearly horizontal; core lengths to 2'.
Shaley Coal: 84.5-84.6'; 85.4-85.5'.
Carbonaceous Lense: 95.2-95.4'.

105.4-106.2' COAL: black; moist; brittle.

106.2-109.0' SILTY SHALE: light gray; moist; cuts easily; sandy; strong HCl reaction; bedding not discernible; single core length.

109.0-122.0' SILTY SANDSTONE: light gray; moist; uncemented; loose to crumbly; very fine grained; strong HCl reaction; bedding not discernible; core lengths to 10".
115.0-116.8' Clayey zone with coal lense from 115.8-115.9'.

122.0-125.0' SILTY SHALE: light gray; moist; cuts easily; sandy; moderate HCl reaction; bedding nearly horizontal; core lengths to 2'.
[illegible] Coal.

125.0-132.0' SILTY SANDSTONE: light gray; moist; uncemented; crumbly; strong

EXPLANATION

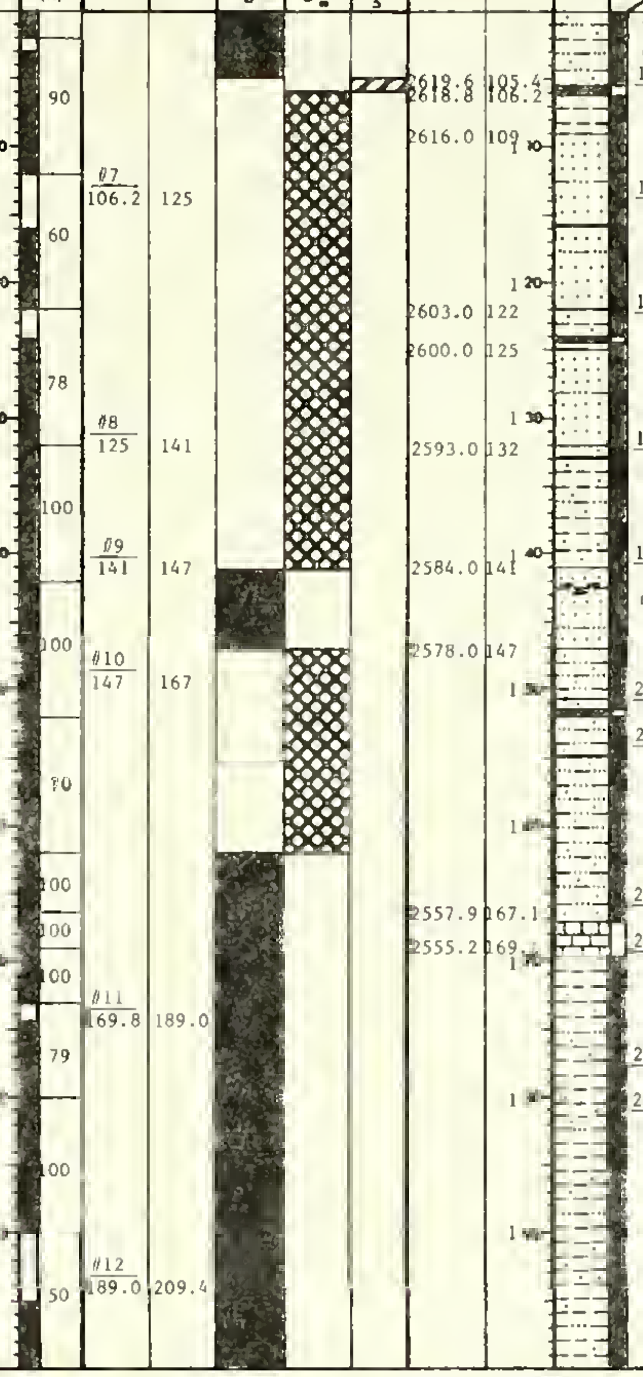
☐ CORE LOSS
■ CORE RECOVERY

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series).. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series).. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series).. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

FEATURE Burns Creek PROJECT EMRIA STATE Montana
HOLE NO. DH81-102 LOCATION 2650'E. & 1950'S. of N.W. Corner Sec. 30, T. 19 N., R. 56 E. GROUND ELEV. 2725'± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 1/19/81 FINISHED 1/29/81 DEPTH OF OVERBURDEN -------- TOTAL DEPTH 270.0' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY



Core recovery (%)
90
60
78
100
100
70
100
100
100
79
100
50

Soils analysis sample	Depth (feet) from	to
#7	106.2	125
#8	125	141
#9	141	147
#10	147	167
#11	169.8	189.0
#12	189.0	209.4

Elevation (feet)	Depth (feet)
2619.6	105.4
2618.8	106.2
2616.0	109
2603.0	122
2600.0	125
2593.0	132
2584.0	141
2578.0	147
2557.9	167.1
2555.2	169.

CLASSIFICATION AND PHYSICAL CONDITION

HCl reaction; bedding not discernible; core lengths to 15".

132.0-141.0' SILTY SHALE: light gray; moist; cuts easily; sandy; moderate HCl reacion; bedding nearly horizontal; core lengths to 2½'.
132.8-132.9' Coal.

141.0-147.0' SILTY SANDSTONE: light gray; moist; uncemented; loose to crumbly; strong HCl reaction; bedding not discernible; core lengths to 4".
142.0-143.0' Carbonaceous Shale.

147.0-167.1' SANDY SILTSTONE: light gray; moist; soft; crumbly; scattered clayey zones; moderate to strong HCl reaction; core lengths to 2'.
Shaley Coal: 150.8-150-9'; 151.5-152.0'; 154.8-155.0'.

167.1-169.8' LIMESTONE: light gray; dry; very hard; silty; conchoidal fractures; much mechanical breakage; strong HCl reaction; bedding not discernible; core lengths to 6".

169.8-209.4' SILTY SHALE: light gray; moist; soft; cuts easily; occasional sandy zones; bottom 2.5' is very sandy; moderate to strong HCl reaction;.bedding not discernible; core length to 2'.

209.4-219.5' COAL: black; moist; brittle.

219.5-226.6' SILTY SHALE: light to medium gray; moist; cuts easily; air slakes; sandy; slight HCl reaction; bedding nearly horizontal; core lengths to 18".
222.0-224.0' Sandstone-Silty, light gray.

226.6-229.7' COAL: black; moist; brittle.

229.7-231-7' SILTY, CARBONACEOUS SHALE: medium to dark gray; moist; cuts easily; slight air slaking; no HCl reaction; bedding nearly horizontal; core lengths to 10".

231.7-252.1' COAL: black; moist; brittle.

252.1-270.0' SANDY SILTSTONE: light gray; moist; very fine grained sand; soft; crumbles easily; strong HCl reaction; bedding nearly horizontal; core lengths to 1'.
267.3-268.0' Coal.
268.0-269.0' Carbonaceous Shale.

EXPLANATION

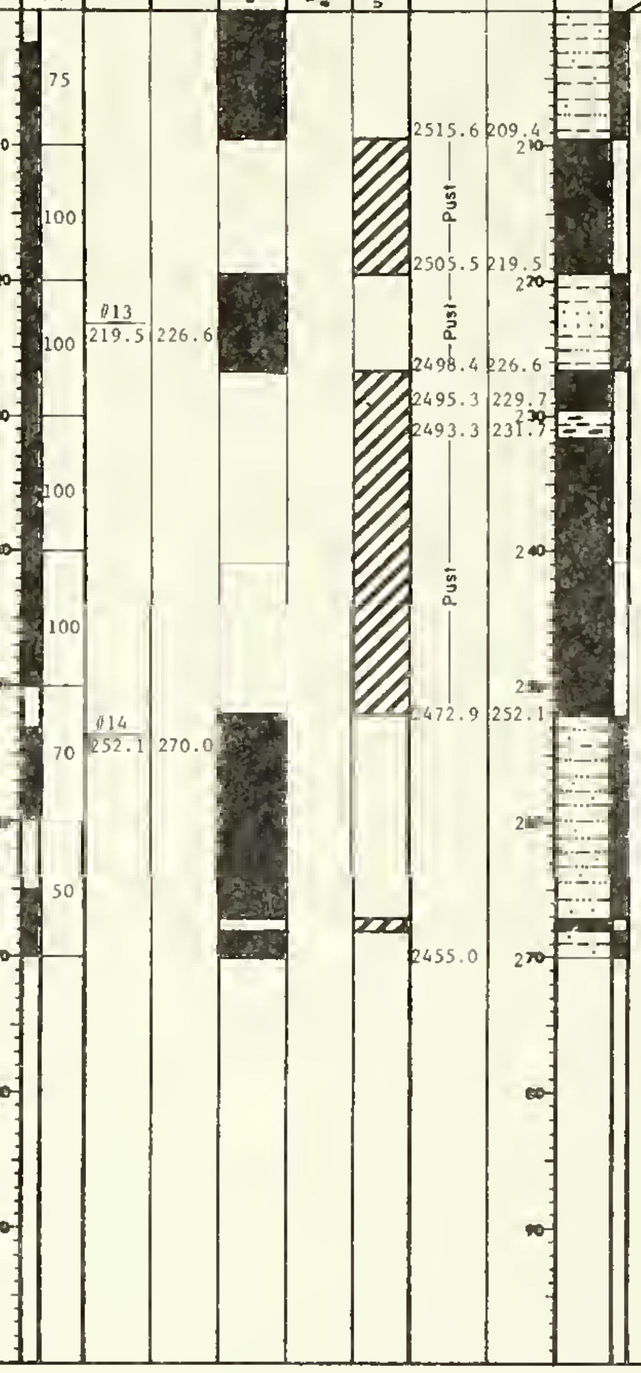
☐ CORE LOSS
■ CORE RECOVERY

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series).. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series).. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series).. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

FEATURE Burns Creek PROJECT EMRIA STATE Montana
HOLE NO. DH81-102 LOCATION 2650'E. & 1950'S. of N.W. Corner Sec. 30, T. 19 N., R. 56 E. GROUND ELEV. 2725'± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 1/19/81 FINISHED 1/29/81 DEPTH OF OVERBURDEN -------- TOTAL DEPTH 270.0' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY



Core recovery (%)
75
100
100
100
100
70
50

Soils analysis sample	Depth (feet) from	to
#13	219.5	226.6
#14	252.1	270.0

Elevation (feet)	Depth (feet)
2515.6	209.4
2505.5	219.5
2498.4	226.6
2495.3	229.7
2493.3	231.7
2472.9	252.1
2455.0	270

EXPLANATION

☐ CORE LOSS
■ CORE RECOVERY

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series).. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series).. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series).. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE AND POTENTIAL RECLAMATION EVALUATION

NORTHEAST MONTANA INVESTIGATIONS
BURNS CREEK STUDY AREA-MONTANA

GEOLOGIC LOG OF DH 81-102

GEOLOGY L. PARISH FIELD APPROVAL
DRAWN TECHNICAL APPROVAL
CHECKED APPROVED

BILLINGS, MONTANA MAY 1983 1305-600-359

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

FEATURE Burns Creek PROJECT EMRIA STATE Montana
HOLE NO. DH81-103 LOCATION 1020'N. & 2720'E. of S.W. Corner COORDS. N. Sec. 24, T. 19 N., R. 55 E. GROUND ELEV. 2725'± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 1-30-81 FINISHED 2-12-81 DEPTH OF OVERBURDEN ------- TOTAL DEPTH 260.0' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Taucher & Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Drill
Failing 1500 truck-mounted.
Driller
R.V. Shaw
Method
Bx drive 0-63'. Hq wireline core 63-260'. Water and Revert used as drill fluid. Losses noted below:

Depth	%Loss
0-35.8'	100
35.8-62'	20
62-130'	100
130-200'	80
200-225'	70
225-260'	100

Casing Record
Set Hw to prevent caving and slow water loss. Pulled all casing on completion of hole.

Depth	Date
0-20.5	1-30-81
20.5-30.5'	2-2-81
30.5-40.5'	1-3-81

Progress Record

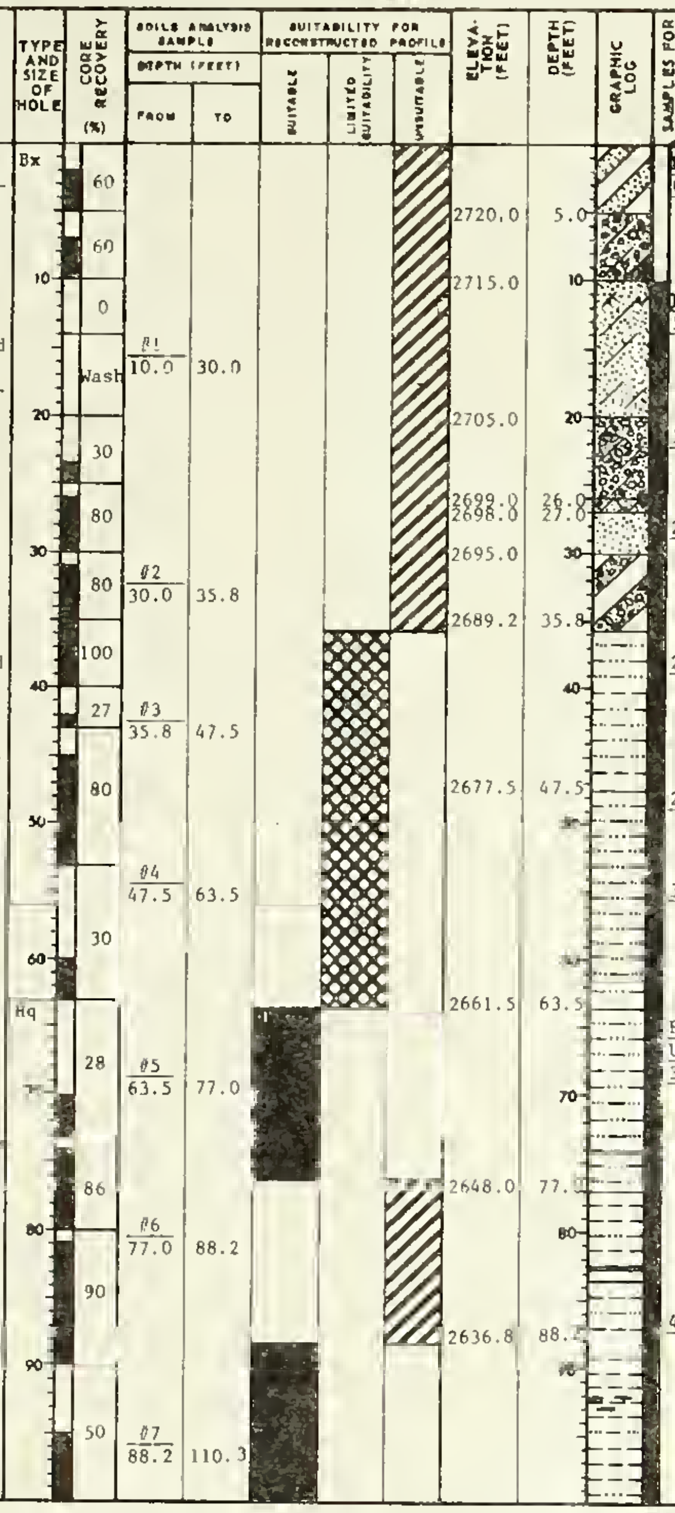
Depth	Date
0-20'	1-30-81
20-30'	2-2-81
30-63'	2-3-81
63-130'	2-4-81
130-200'	2-5-81

Too cold to drill on 2-10-81.

200-260'	2-11-81

Completed hole on 2-12-81.
Hole Completion
Pulled all casing and backfilled hole 2-12-81.
Water Levels
Not Stabilized.

Depth	Date
Ory to 20'	2-2-81
Ory to 30'	2-3-81
Dry to 63'	2-4-81
96'	2-5-81
97.3'	2-11-81
164'	2-12-81



CLASSIFICATION AND PHYSICAL CONDITION

HOLOCENE - EOLIAN?

0-5.0' SILTY SAND: dark gray and organic 0-1'; tan 1-5'; damp to moist; approx. 35% nonplastic fines; 65% fine uniform aand; few roots; active HCl reaction; wind blown. (SM)

LATE TERTIARY - FLAXVILLE GRAVEL?

5.0'-10.0' SAND & GRAVEL: gray-brown; slightly oxidized; moist; approx. 40% fine to coarse sand; 50% fine to medium, aubrounded gravel to 1"; 10% nonplastic fines. (GP-GM)

10.0-20.0' SAND: gray-brown; slightly oxidized; moist; approx. 90% fine to medium sand; 10% nonplastic fines; only wash was recovered. (SP-SM)

20.0-26.0' SAND & GRAVEL: gray-brown; slightly oxidized; moist; approx. 50% fine to medium, hard, subrounded gravel to 1¼": 40% moatly fine to medium sand; 10% nonplastic fines; uncemented. (GP-GM)

26.0-27.0' SAND & GRAVEL: gray-tan; damp to moist; slightly oxidized; uncemented; approx. 35% fine, hard, subrounded gravel to 1"; 10% nonplastic finea: 55% mostly fine, uniform sand. (SP-SM)

27.0-30.0' SAND: tan; dry; slightly oxidized; approx. 95% fine, uniform sand; 5% nonplaatic fines; uncemented. (SP)

30.0-35.8' SILTY SAND & GRAVEL: tan; oxidized; moist; slight HCl reaction; uncemented: approx 15% low tp nonplastic fines; 45% fine to medium, hard, subrounded to subangular gravel to 1½"; 40% mostly fine sand. (GM)

PALEOCENE - TONGUE RIVER MEMBER - FORT UNION FORMATION

35.8-47.5' CLAYEY SILTSTONE: yellow-tan; moist: oxidized: slight HCl reaction: occasional 1/8 to ¼" gypaum atringer; uncemented: trims easily with knife; bedding not readily discernible; core broken by drilling along irregular, nearly horizontal planea on 1 to 26" lengths (Average 6"): low plasticity; breaka down to (ML-CL) or (ML).
38.2' Two oppoaing 90° iron stained jointa.

47.5-63.5' SILTSTONE: yellow-tan; oxidized; moist; weak to moderate HCl reaction; similar to material 35.8-47.5' but is less plastic; uncemented: cuts easily with knife; broken by drilling along irregular, nearly horizontal planes on about 6" centers; breaks down to (ML).

EXPLANATION

▯ CORE LOSS
▮ CORE RECOVERY

Type of hole .... D = Diamond, H = Hoysrellite, S = Shot, C = Churn
Hole sealed .... P = Pocker, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

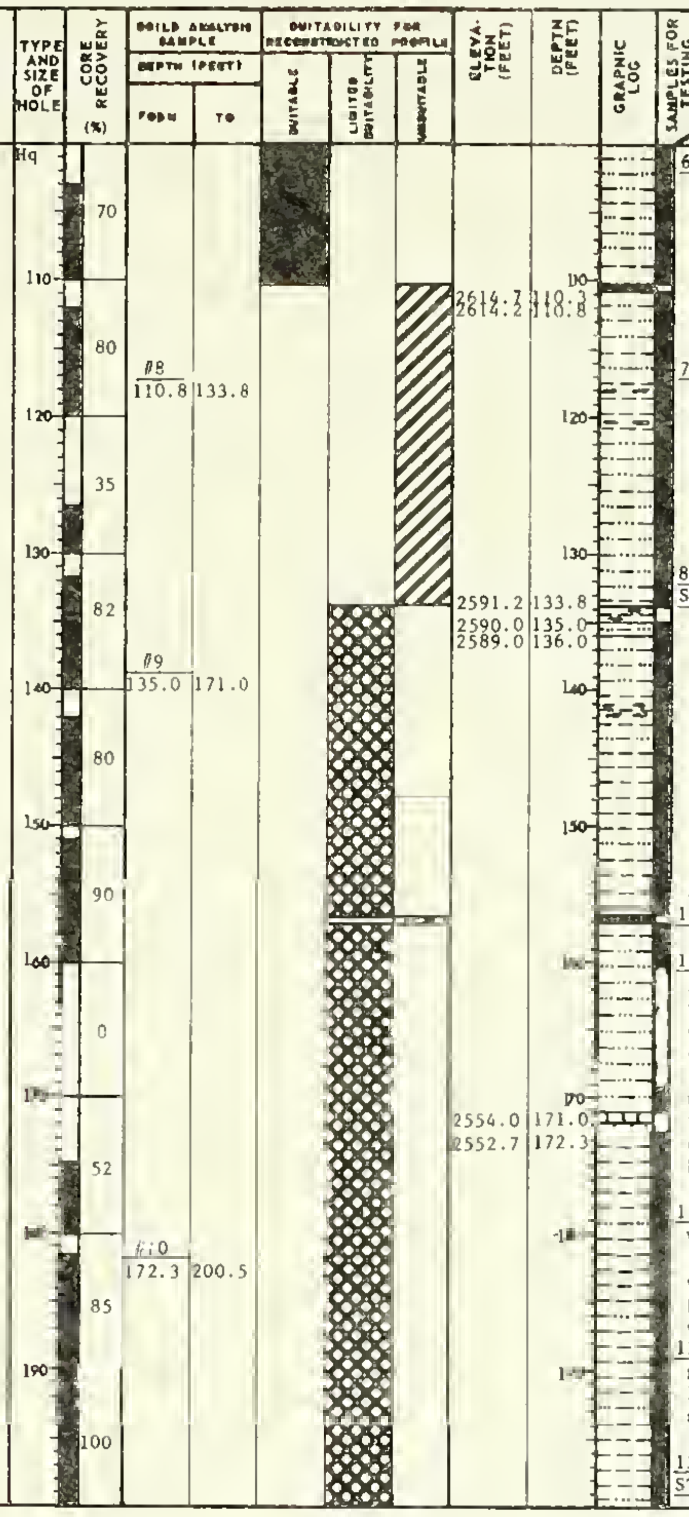
FEATURE Burns Creek PROJECT EMRIA STATE Montana SHEET 1 OF 3 HOLE NO. DH81-103

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

FEATURE Burns Creek PROJECT EMRIA STATE Montana
HOLE NO. DH81-103 LOCATION 1020'N. & 2720'E. of S.W. Corner COORDS. N. Sec. 24 T. 19 N., R. 55 E. GROUND ELEV. 2725'± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 1-30-81 FINISHED 2/12/81 DEPTH OF OVERBURDEN ------- TOTAL DEPTH 260.0' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Taucher & Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS



CLASSIFICATION AND PHYSICAL CONDITION

63.5-77.0' CLAYEY SILTSTONE: light gray; moist; unoxidized; weak HCl reaction; uncemented; cuta easily with knife; bedding not readily discernihle; broken by drilling along irregular, nearly horizontal planes on 1 to 3" centers; low to medium plaaticity 63-66'; low plasticity below 66'; soft coal 74-74.1'; breaks down to (CL) or (ML-CL).

77.0-88.2' SILTY SHALE: light gray: moist; unoxidized; weak HCl reaction; firm; trims with some difficulty; medium plasticity; air slakea; bedding not discernible in moat places; broken by drilling along horizontal planea on 1-14" centers (Average 10"); ½" coal at 82.5' and 82.6'; breaks down to (CL).
83.4-83.5' Coal.

88.2-110.3' SILTY SHALE & CLAYEY SILTSTONE: light gray; moist; weak HCl reaction; uncemented; trima easiy with knife: bedding generally not diacernible; core broken by drilling along horizontal planes in ahales and irregular, varioua dipping planea in ailtstonea; thin bedded to banded 1D2.8-104'; medium plasticity ahale 90-91.2'; 91.8-92.5' (dark gray to black carbonaceous shale cut by 40-50° slickensides 92.2-92.5'); 100-101.7' and 109.6-110.3'; remaining material ls low plaaticity clayey siltstone; breaks down to (ML-CL) and (CL).

110.3-110.8' COAL: broken on horizontal planea on 1-3" centers.

110.8-133.8' CLAYEY SILTSTONE: light gray; moist; weak HCl reaction; bedding not readily discernible; core hroken by drilling along horizontal planea on 1-24" centers (Average 12"); low to medium plasticity; containa root and tree fragments; cuta easily with knife; black, plastic, carbonaceous shale 117.9-119.1'; core begins to waah away along root holes filled with carbonaceous material 120-120.8'; breaka down to (ML-CL).

133.8-135.0' SHALE: dark gray; plaatic; weak HCl reaction; mottled in upper and lower parta; bedding not readily discernible; core breaka along horizontal planes; trima easily with knife; 3/8" coal at 133.8'; breaka down to (CH).

135.0-136.0' SILTSTONE: light gray and green mottled; moist; weak HCl reaction; low plasticity; trima easily with knife; no bedding discernible; breaks down to (ML).

136.0-171.0' SILTY SHALE & CLAYEY SILTSTONE: light gray: moist; weak HCl

EXPLANATION

▯ CORE LOSS
▮ CORE RECOVERY

Type of hole .... D = Diamond, H = Hoysrellite, S = Shot, C = Churn
Hole sealed .... P = Pocker, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"

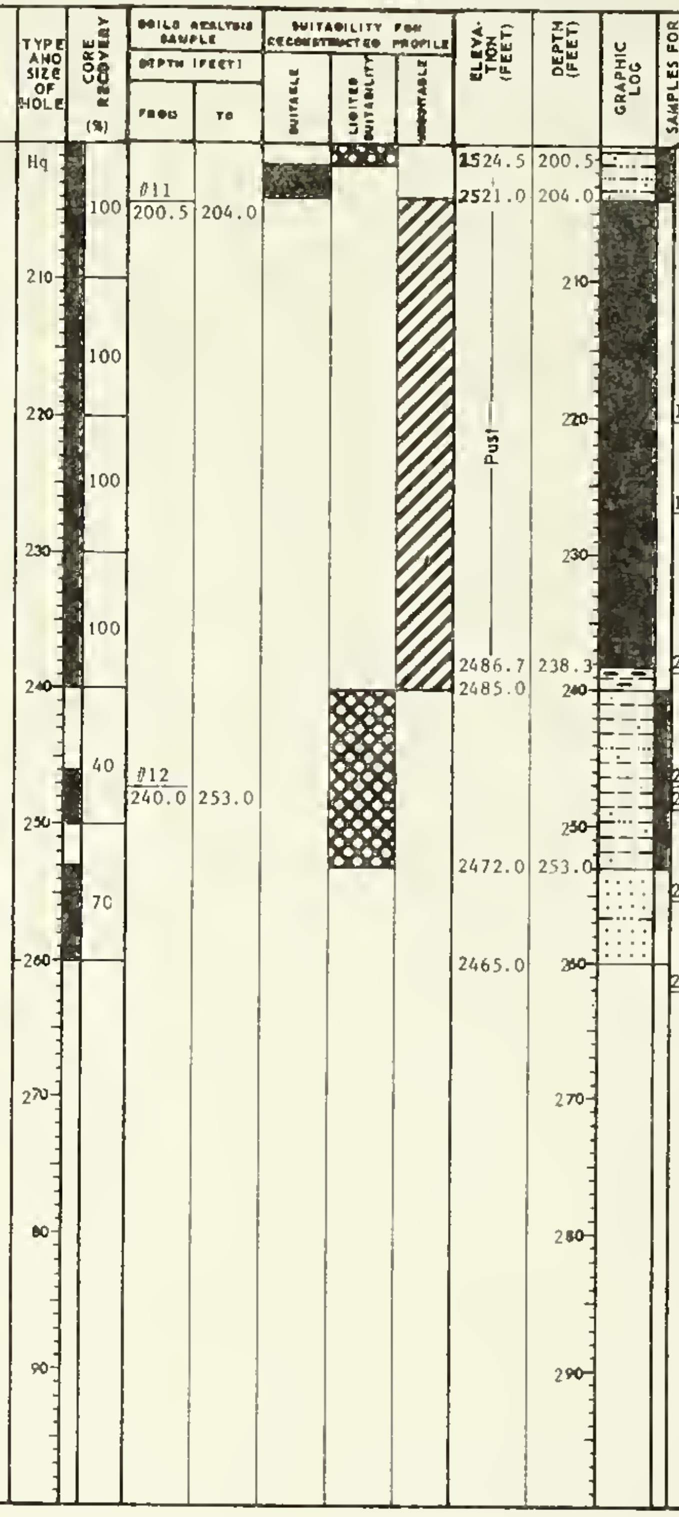
FEATURE Burns Creek PROJECT EMRIA STATE Montana SHEET 2 OF 3 HOLE NO. DH81-103

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

FEATURE Burns Creek PROJECT EMRIA STATE Montana
HOLE NO. DH81-103 LOCATION 1020'N. & 2720'E. of S.W. Corner COORDS. N. Sec. 24, T. 19 N., R. 55 E. GROUND ELEV. 2725'± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 1/30/81 FINISHED 2/12/81 DEPTH OF OVERBURDEN ------- TOTAL DEPTH 260.0' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Taucher & Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS



CLASSIFICATION AND PHYSICAL CONDITION

reaction; bedding not readily discernible; core breaks along nearly horizontal planes in plastic shales and along irregular dipping planes in siltstones: trims easily with knife; silty ahale 139.8-142.0'; 146.0-156.4' and 157.0-157.5'; coal at 156.4-157.0' ; ½" coal at 156.0'; black carbonaceous atreaks 141.8-141.9'; remaining material is clayey siltstone; breaks down to (ML-CL) or (CL).

171.0-172.3 LIMESTONE: light gray; active HCl reaction; very hard; scratches with knife: contains ailt and clay contamination; horizontally bedded.

172.3-200.5' SILTY SHALE: light gray; moist; cuta easily with knife; medium plaaticity; bedding not readily discernible; slight to moderate HCl reaction; broken hy drilling along nearly horizontal planes on 1-18" centers; breaka down to (CL).

200.5-204.0' SANDY SILTSTONE: gray; moist; soft; crumbles eaaily; aand very fine and micaceous; scattered pyrite nodules; moderate HCl reaction; bedding nearly horizontal; core lengths to 10".

204.0-238.3 COAL: black; moist; brittle.

238.3-240.0' CARBONACEOUS SHALE: dark gray; moist; soft; breaka easily; sandy; bedding not diacernible; no HCl reaction; core lengths to 4".

240.0-253.0' SILTY SHALE: gray; moist; soft; crumbles eaaily; sandy; no HCl reaction; bedding not diacernible; core lengths to 6".

253.0-260.0' SILTY SANDSTONE: gray; wet; uncemented: crumbles easily; fine grained; strone HCl reaction; bedding not discernible; core lengths to 4".

EXPLANATION

▯ CORE LOSS
▮ CORE RECOVERY

Type of hole .... D = Diamond, H = Hoysrellite, S = Shot, C = Churn
Hole sealed .... P = Pocker, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Burns Creek PROJECT EMRIA STATE Montana SHEET 3 OF 3 HOLE NO. DH81-103

Depth on logs in feet.
[illegible]

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE AND POTENTIAL RECLAMATION EVALUATION
NORTHEAST MONTANA INVESTIGATIONS
BURNS CREEK STUDY AREA-MONTANA

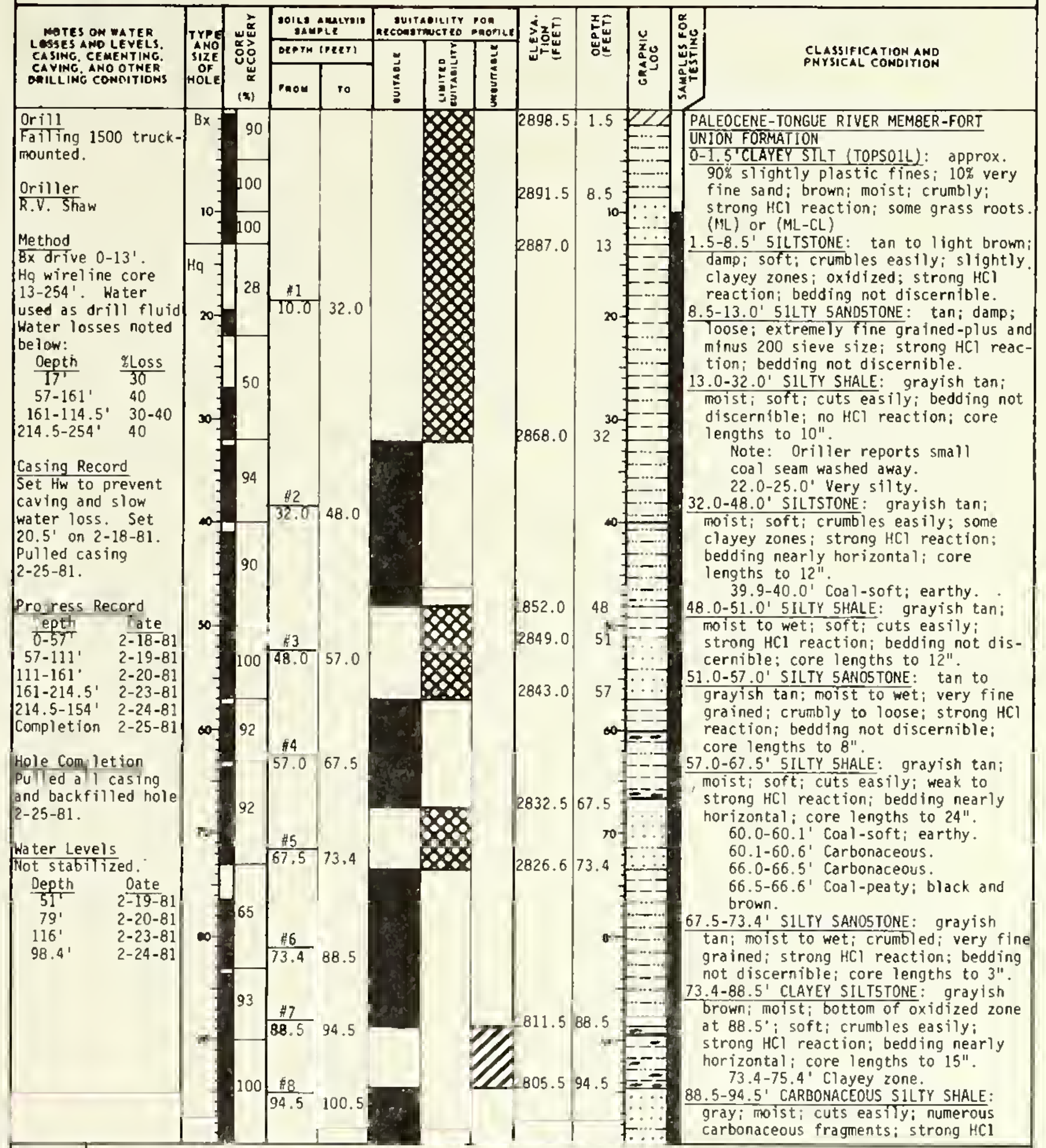
GEOLOGIC LOG OF DH 81-103

GEOLOGY G. TAUCHER L. PARISH FIELD APPROVAL
DRAWN TECHNICAL APPROVAL
CHECKED APPROVED
BILLINGS, MONTANA MAY 1983 1305-600-360

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

FEATURE Upper Thirteenmile Creek PROJECT EMRIA STATE Montana
HOLE NO. DH81-104 LOCATION 2925' N. & 100' E. of S.W. Corner Sec. 8, T. 20 N., R. 53 E. GROUND ELEV. 2900'± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 2-18-81 FINISHED 2-25-81 DEPTH OF OVERBURDEN ------ TOTAL DEPTH 254.0' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY



NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS
TYPE AND SIZE OF HOLE
CORE RECOVERY (%)
SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM TO
SUITABILITY FOR RECONSTRUCTED PROFILE
SUITABLE
LIMITED SUITABILITY
UNSUITABLE
ELEVATION (FEET)
DEPTH (FEET)
GRAPHIC LOG
SAMPLES FOR TESTING
CLASSIFICATION AND PHYSICAL CONDITION
Bx
Hq
10
20
30
40
50
60
70
80
90

Drill
Failing 1500 truck-mounted.

Driller
R.V. Shaw

Method
Bx drive 0-13'. Hq wireline core 13-254'. Water used as drill fluid. Water losses noted below:

Depth	%Loss
17'	30
57-161'	40
161-114.5'	30-40
214.5-254'	40

Casing Record
Set Hw to prevent caving and slow water loss. Set 20.5' on 2-18-81. Pulled casing 2-25-81.

Progress Record

Depth	Date
0-57'	2-18-81
57-111'	2-19-81
111-161'	2-20-81
161-214.5'	2-23-81
214.5-154'	2-24-81
Completion	2-25-81

Hole Completion
Pulled all casing and backfilled hole 2-25-81.

Water Levels
Not stabilized.

Depth	Date
51'	2-19-81
79'	2-20-81
116'	2-23-81
98.4'	2-24-81

Core recovery (%): 90, 100, 100, 28, 50, 94, 90, 100, 92, 92, 65, 93, 100

Soils analysis sample	From	To
#1	10.0	32.0
#2	32.0	48.0
#3	48.0	57.0
#4	57.0	67.5
#5	67.5	73.4
#6	73.4	88.5
#7	88.5	94.5
#8	94.5	100.5

Elevation (feet)	Depth (feet)
2898.5	1.5
2891.5	8.5
2887.0	13
2868.0	32
2852.0	48
2849.0	51
2843.0	57
2832.5	67.5
2826.6	73.4
811.5	88.5
805.5	94.5

PALEOCENE-TONGUE RIVER MEMBER-FORT UNION FORMATION

0-1.5' CLAYEY SILT (TOPSOIL): approx. 90% slightly plastic fines; 10% very fine sand; brown; moist; crumbly; strong HCl reaction; some grass roots. (ML) or (ML-CL)

1.5-8.5' SILTSTONE: tan to light brown; damp; soft; crumbles easily; slightly clayey zones; oxidized; strong HCl reaction; bedding not discernible.

8.5-13.0' SILTY SANDSTONE: tan; damp; loose; extremely fine grained-plus and minus 200 sieve size; strong HCl reaction; bedding not discernible.

13.0-32.0' SILTY SHALE: grayish tan; moist; soft; cuts easily; bedding not discernible; no HCl reaction; core lengths to 10".
  Note: Driller reports small coal seam washed away.
  22.0-25.0' Very silty.

32.0-48.0' SILTSTONE: grayish tan; moist; soft; crumbles easily; some clayey zones; strong HCl reaction; bedding nearly horizontal; core lengths to 12".
  39.9-40.0' Coal-soft; earthy.

48.0-51.0' SILTY SHALE: grayish tan; moist to wet; soft; cuts easily; strong HCl reaction; bedding not discernible; core lengths to 12".

51.0-57.0' SILTY SANDSTONE: tan to grayish tan; moist to wet; very fine grained; crumbly to loose; strong HCl reaction; bedding not discernible; core lengths to 8".

57.0-67.5' SILTY SHALE: grayish tan; moist; soft; cuts easily; weak to strong HCl reaction; bedding nearly horizontal; core lengths to 24".
  60.0-60.1' Coal-soft; earthy.
  60.1-60.6' Carbonaceous.
  66.0-66.5' Carbonaceous.
  66.5-66.6' Coal-peaty; black and brown.

67.5-73.4' SILTY SANDSTONE: grayish tan; moist to wet; crumbled; very fine grained; strong HCl reaction; bedding not discernible; core lengths to 3".

73.4-88.5' CLAYEY SILTSTONE: grayish brown; moist; bottom of oxidized zone at 88.5'; soft; crumbles easily; strong HCl reaction; bedding nearly horizontal; core lengths to 15".
  73.4-75.4' Clayey zone.

88.5-94.5' CARBONACEOUS SILTY SHALE: gray; moist; cuts easily; numerous carbonaceous fragments; strong HCl

EXPLANATION

▯ CORE LOSS
▮ CORE RECOVERY

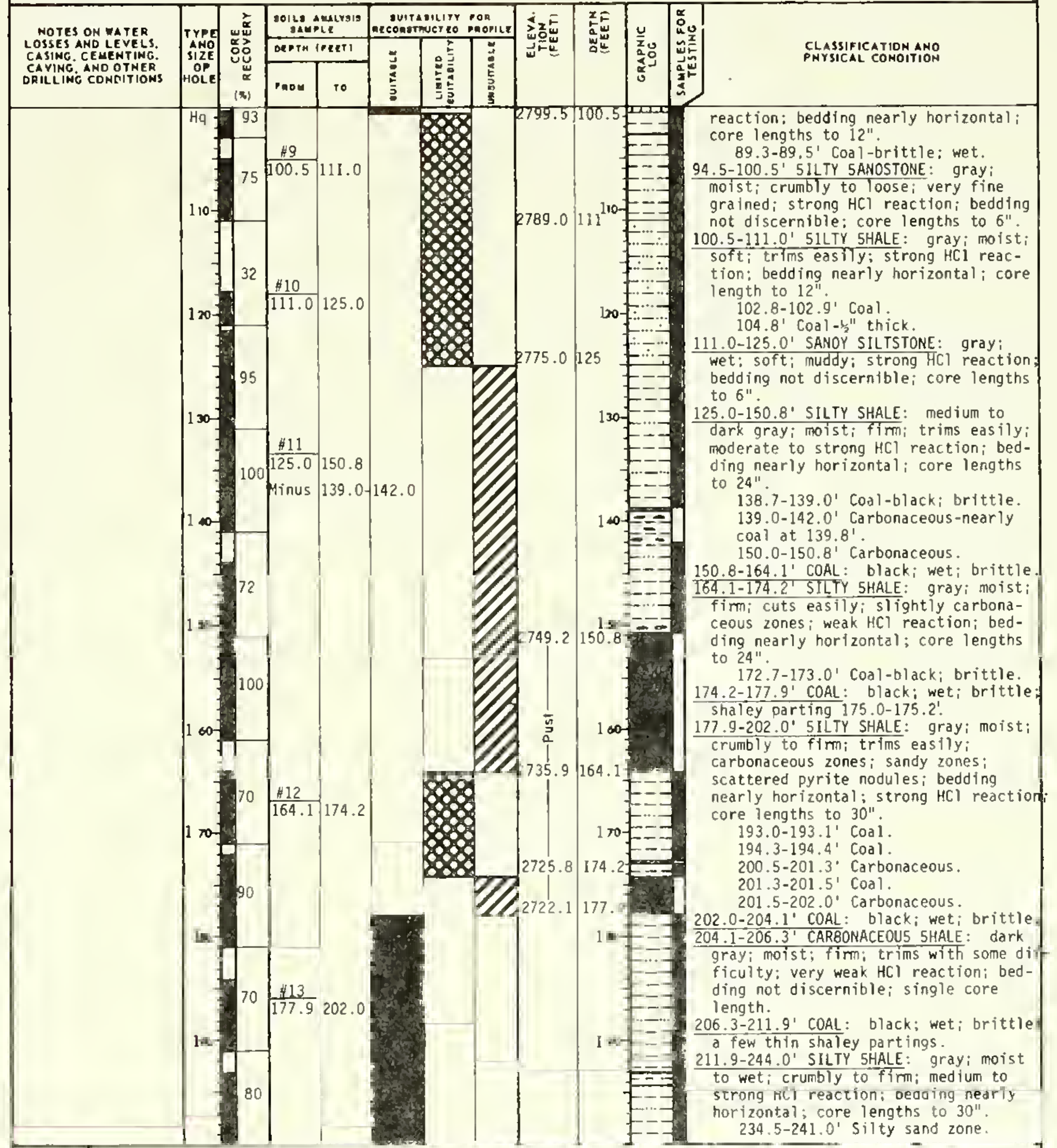
Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Upper Thirteenmile Creek PROJECT EMRIA STATE Montana SHEET 1 OF 3 HOLE NO. DH81-104

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

FEATURE Upper Thirteenmile Creek PROJECT EMRIA STATE Montana
HOLE NO. DH81-104 LOCATION 2925' N. & 100' E of S.W. Corner Sec. 8, T. 20 N., R. 53 E. GROUND ELEV. 2900'± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 2-18-81 FINISHED 2-25-81 DEPTH OF OVERBURDEN ------ TOTAL DEPTH 254.0' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY



NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS
TYPE AND SIZE OF HOLE
CORE RECOVERY (%)
SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM TO
SUITABILITY FOR RECONSTRUCTED PROFILE
SUITABLE
LIMITED SUITABILITY
UNSUITABLE
ELEVATION (FEET)
DEPTH (FEET)
GRAPHIC LOG
SAMPLES FOR TESTING
CLASSIFICATION AND PHYSICAL CONDITION
Hq
110
120
130
140
150
160
170
180
190
Pust

Core recovery (%): 93, 75, 32, 95, 100, 72, 100, 70, 90, 70, 80

Soils analysis sample	From	To
#9	100.5	111.0
#10	111.0	125.0
#11	125.0	150.8
Minus	139.0	142.0
#12	164.1	174.2
#13	177.9	202.0

Elevation (feet)	Depth (feet)
2799.5	100.5
2789.0	111
2775.0	125
2749.2	150.8
2735.9	164.1
2725.8	174.2
2722.1	177.

reaction; bedding nearly horizontal; core lengths to 12".
  89.3-89.5' Coal-brittle; wet.

94.5-100.5' SILTY SANDSTONE: gray; moist; crumbly to loose; very fine grained; strong HCl reaction; bedding not discernible; core lengths to 6".

100.5-111.0' SILTY SHALE: gray; moist; soft; trims easily; strong HCl reaction; bedding nearly horizontal; core length to 12".
  102.8-102.9' Coal.
  104.8' Coal-½" thick.

111.0-125.0' SANDY SILTSTONE: gray; wet; soft; muddy; strong HCl reaction; bedding not discernible; core lengths to 6".

125.0-150.8' SILTY SHALE: medium to dark gray; moist; firm; trims easily; moderate to strong HCl reaction; bedding nearly horizontal; core lengths to 24".
  138.7-139.0' Coal-black; brittle.
  139.0-142.0' Carbonaceous-nearly coal at 139.8'.
  150.0-150.8' Carbonaceous.

150.8-164.1' COAL: black; wet; brittle.

164.1-174.2' SILTY SHALE: gray; moist; firm; cuts easily; slightly carbonaceous zones; weak HCl reaction; bedding nearly horizontal; core lengths to 24".
  172.7-173.0' Coal-black; brittle.

174.2-177.9' COAL: black; wet; brittle; shaley parting 175.0-175.2'.

177.9-202.0' SILTY SHALE: gray; moist; crumbly to firm; trims easily; carbonaceous zones; sandy zones; scattered pyrite nodules; bedding nearly horizontal; strong HCl reaction; core lengths to 30".
  193.0-193.1' Coal.
  194.3-194.4' Coal.
  200.5-201.3' Carbonaceous.
  201.3-201.5' Coal.
  201.5-202.0' Carbonaceous.

202.0-204.1' COAL: black; wet; brittle.

204.1-206.3' CARBONACEOUS SHALE: dark gray; moist; firm; trims with some difficulty; very weak HCl reaction; bedding not discernible; single core length.

206.3-211.9' COAL: black; wet; brittle; a few thin shaley partings.

211.9-244.0' SILTY SHALE: gray; moist to wet; crumbly to firm; medium to strong HCl reaction; bedding nearly horizontal; core lengths to 30".
  234.5-241.0' Silty sand zone.

EXPLANATION

▯ CORE LOSS
▮ CORE RECOVERY

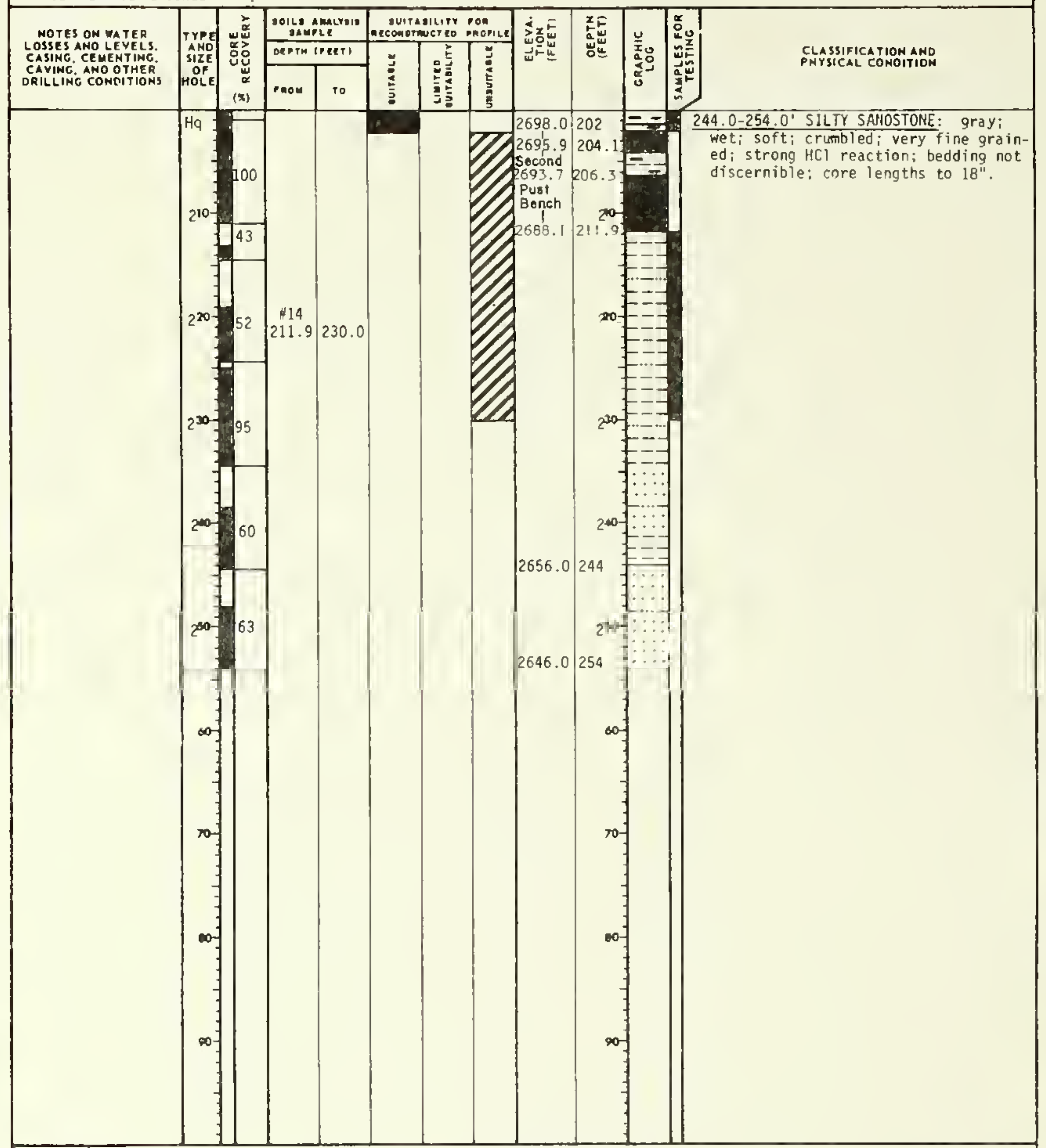
Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Upper Thirteenmile Creek PROJECT EMRIA STATE Montana SHEET 2 OF 3 HOLE NO. DH81-104

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

FEATURE Upper Thirteenmile Creek PROJECT EMRIA STATE Montana
HOLE NO. DH81-104 LOCATION 2925' N. & 100' E. of S.W. Corner Sec. 8, T. 20 N., R. 53 E. GROUND ELEV. 2900'± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 2-18-81 FINISHED 2-25-81 DEPTH OF OVERBURDEN ------ TOTAL DEPTH 254.0' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY



NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS
TYPE AND SIZE OF HOLE
CORE RECOVERY (%)
SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM TO
SUITABILITY FOR RECONSTRUCTED PROFILE
SUITABLE
LIMITED SUITABILITY
UNSUITABLE
ELEVATION (FEET)
DEPTH (FEET)
GRAPHIC LOG
SAMPLES FOR TESTING
CLASSIFICATION AND PHYSICAL CONDITION
Hq
210
220
230
240
250
60
70
80
90

Core recovery (%): 100, 43, 52, 95, 60, 63

Soils analysis sample	From	To
#14	211.9	230.0

Elevation (feet)	Depth (feet)
2698.0	202
2695.9	204.1
Second 2693.7	206.3
Pust Bench 2688.1	211.9
2656.0	244
2646.0	254

244.0-254.0' SILTY SANDSTONE: gray; wet; soft; crumbled; very fine grained; strong HCl reaction; bedding not discernible; core lengths to 18".

EXPLANATION

▯ CORE LOSS
▮ CORE RECOVERY

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Upper Thirteenmile Creek PROJECT EMRIA STATE Montana SHEET 3 OF 3 HOLE NO. DH81-104

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE AND POTENTIAL RECLAMATION EVALUATION
NORTHEAST MONTANA INVESTIGATIONS
UPPER THIRTEENMILE CREEK STUDY AREA-MONTANA

GEOLOGIC LOG OF DH 81-104

GEOLOGY L. PARISH FIELD APPROVAL
DRAWN TECHNICAL APPROVAL
CHECKED APPROVED
BILLINGS, MONTANA MAY 1983 1305-600-361

Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE Upper Thirteenmile Creek PROJECT EMRIA STATE Montana
HOLE NO. DH81-105 LOCATION 792'W.& 125'S. of NE. Corner Sec. 32, T. 21 N., R. 53 E. GROUND ELEV. 2810'± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 2-25-81 FINISHED 3-4-81 DEPTH OF OVERBURDEN ------ TOTAL DEPTH 198.0' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Drill
Failing 1500 truck-mounted.

Driller
R.V. Shaw

Method
Bx drive samples 0-10'. Hq wireline core 10-198'. Water and Revert used as drill fluid. Water losses during drilling noted below:

Depth	%Loss
114-181'	25
181-198'	20

Casing Record
Set 10.5' of Hw casing on 2-25-81 to prevent caving at top of hole. Pulled 3-4-81.

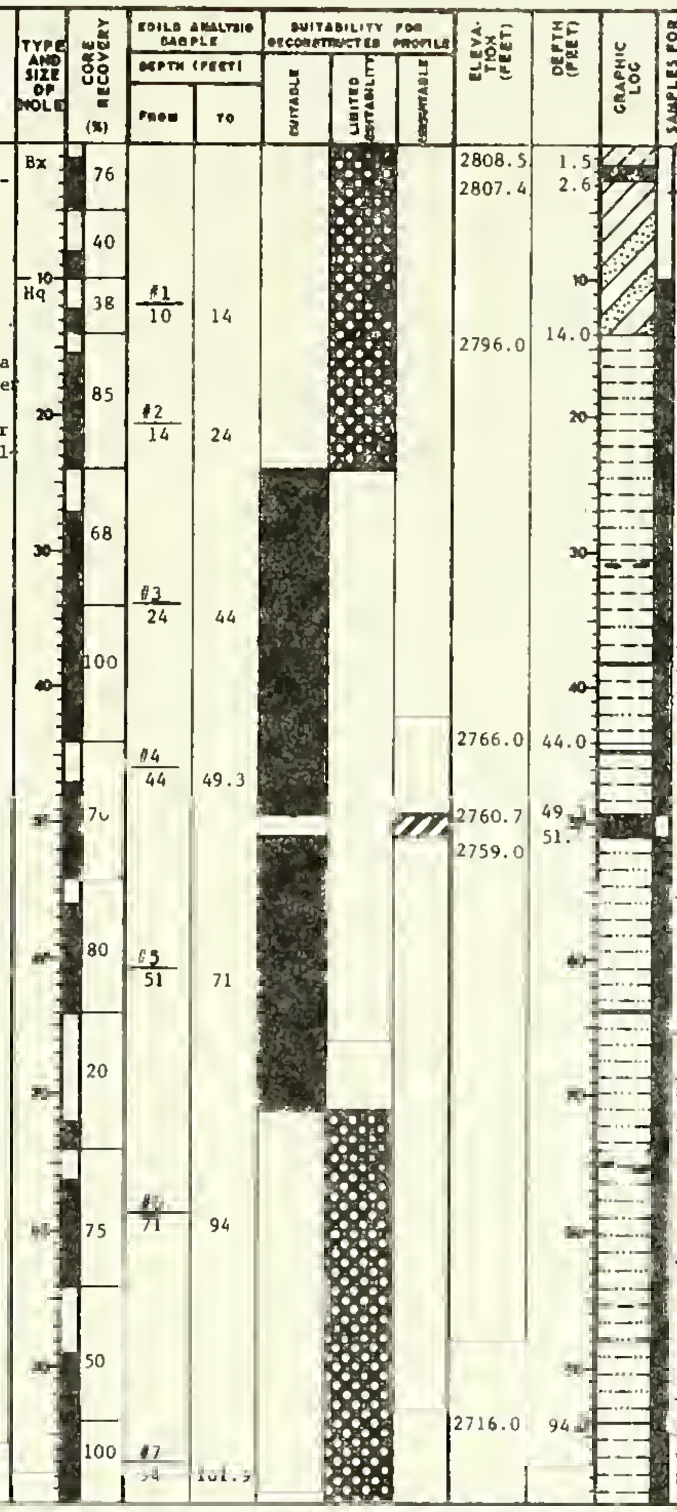
Progress Record

Depth	Date
0-44'	2-25-81
44-114'	2-26-81
114-181.7'	3-3-81
181.7-198'	3-4-81

Hole Completion
Pulled casing and backfilled hole 3-4-81.

Water Levels
Not stabilized.

Depth	Date
33.5'	2-26-81
47.5'	3-3-81
46'	3-4-81



Sample	From	To
#1	10	14
#2	14	24
#3	24	44
#4	44	49.3
#5	51	71
#6	71	94
#7	94	101.9

CLASSIFICATION AND PHYSICAL CONDITION

HOLOCENE
0-1.5' TOPSOIL: approx. 90% low plasticity fines; 10% mostly fine sand; scattered gravels to 3/4" diameter; dark brown; moist; crumbly; abundant grass roots; no HCl reaction;. (CL)
PLEISTOCENE DEPOSITS?
1.5-2.6' GRAVEL: approx. 55% subrounded to subangular gravel to 1¼"; 35% fine to coarse sand; 10% slightly plastic fines; light brown; damp; loose; some caliche; strong HCl reaction. (GP-GM)
2.6-14.0' SANDY SILT to SILTY SAND: silt content decreases with depth; varies from approx. 65% nonplastic fines with 35% extremely fine sand to 70% extremely fine sand with 30% nonplastic fines; tan; damp; loose to crumbly; strong HCl reaction; slightly clayey 9-10'; scattered, rounded igneous gravels to ½" from 13.5-14.0'. (ML) to (SM)
PALEOCENE - TONGUE RIVER MEMBER - FORT UNION FORMATION
14.0-44.0' SILTY SHALE: light brown; moist; crumbles and cuts easily; very silty throughout and contains zones of siltstone; moderate HCl reaction; bedding nearly horizontal; core lengths to 2'.
30.9-31.0' Carbonaceous shale and soft, earthy coal.
38.0-38.2' Coal.
44.0-49.3' SHALE: light gray; moist; trims easily; silty; moderate HCl reaction; bedding not discernible; core lengths to 3'.
44.5-44.7' Shaley Coal-black; soft; more clay than coal.
49.3-51.0' SHALEY COAL: black and dark gray; about as much shale as coal.
51.0-94.0' CLAYEY SILTSTONE: light gray; moist; cuts easily; scattered silty shale zones; moderate to strong HCl reaction; bedding nearly horizontal; core lengths to 3'.
63.7-63.9' Coal-black; shaley.
74.0' Coal-½" thick.
75.0-75.2' Carbonaceous.
94.0-101.9' SHALE: medium gray; moist; firm; trims easily; no HCl reaction; occasional ¼" diameter pyrite nodules; bedding nearly horizontal; core lengths to 3½'.
100.0 Coal-¼" thick.
101.9-124.2' COAL: black; wet; brittle.
124.2-134.0' SILTSTONE: almost no recovery; driller reported that sample washed away during drilling; shoe of barrel contained a pyritic coal bed approx. 1" thick.

EXPLANATION

▯ CORE LOSS
▮ CORE RECOVERY

Type of hole . . . . D = Diamond, H = Hayzeillite, S = Shot, C = Churn
Hole sealed . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
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FEATURE Upper Thirteenmile Creek PROJECT EMRIA STATE Montana SHEET 1 OF 2 HOLE NO. DH81-105

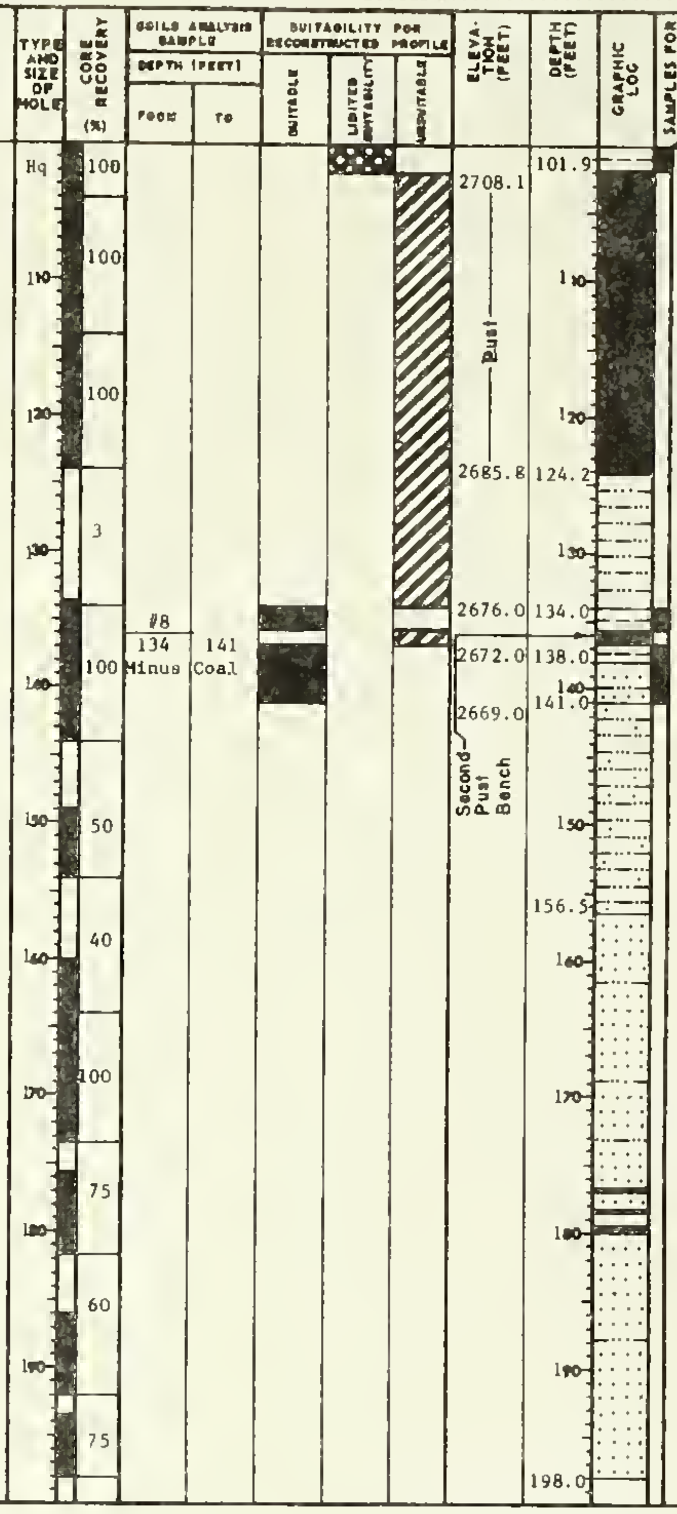
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

FEATURE Upper Thirteenmile Creek PROJECT EMRIA STATE Montana
HOLE NO. DH81-105 LOCATION 792'W.& 125'S. of NE. Corner Sec. 32, T. 21 N., R. 53 E. GROUND ELEV. 2810'± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 2-25-81 FINISHED 3-4-81 DEPTH OF OVERBURDEN ------ TOTAL DEPTH 198.0' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS



Sample	From	To
#8	134 Minus	141 Coal

CLASSIFICATION AND PHYSICAL CONDITION

134.0-138.0' SILTY SHALE: medium gray; moist; cuts easily; slightly carbonaceous; no HCl reaction; bedding nearly horizontal; core lengths to 8".
135.8-136.8' Coal.
138.0-141.0' SILTY SANDSTONE: medium gray; wet; crumbled; fine grained; no HCl reaction; bedding not discernible; core lengths to 2".
141.0-156.5' SANDY SILTSTONE: medium gray; wet; crumbles easily; weak HCl reaction; bedding not discernible; core lengths to 6".
156.5-198.0' SILTY SANDSTONE: gray; wet; crumbly to loose; silt content decreases with depth; fine grained; moderate HCl reaction; bedding not discernible; core lengths to 15".
176.7-177.0' Coal-woody; light weight.
178.3-178.6' Coal-see above.
179.5-180.0' Coal-soft; peaty; shaley.

EXPLANATION

▯ CORE LOSS
▮ CORE RECOVERY

Type of hole . . . . D = Diamond, H = Hayzeillite, S = Shot, C = Churn
Hole sealed . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
[illegible]

FEATURE Upper Thirteenmile Creek PROJECT EMRIA STATE Montana SHEET 2 OF 2 HOLE NO. DH81-105

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE AND POTENTIAL RECLAMATION EVALUATION
NORTHEAST MONTANA INVESTIGATIONS
UPPER THIRTEENMILE CREEK STUDY AREA-MONTANA

GEOLOGIC LOG OF DH 81-105

GEOLOGY L. PARISH FIELD APPROVAL
DRAWN TECHNICAL APPROVAL
CHECKED APPROVED
BILLINGS, MONTANA MAY 1983 1305-600-362

PLATE 21

7-1337 (9-49)
Bureau of Reclamation
GPO 864-461

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE S.W. Glendive PROJECT EMRIA STATE Montana
HOLE NO. DH81-106 LOCATION COORDS. 3.0' N. 620.0' W. of S.E. Corner Section 14; T15N., R53E. GROUND ELEV. 2575± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 3/11/81 FINISHED 3/16/81 DEPTH OF OVERBURDEN ——— TOTAL DEPTH 140.0' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Botdorf LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Drill
Failing 314-C truck mounted.
Driller
R.V. Shaw
Method
Bx drive 0-15 ft.,
3-7/8 in. rockbit:
15.0 to 20.0 ft.
25.0 to 29.0 ft.
52.0 to 54.0 ft.
70.0 to 77.4 ft.
Hq wireline core:
20.0 to 25.0 ft.
29.0 to 52.0 ft.
54.0 to 70.0 ft.
77.4 to 140.0 ft.
Water
Water used as drill fluid. Losses noted below:

Depth	% Loss
70.0'	20
101.7-113.0'	40

Casing Record

3/12/81	40'	Hw
3/13/81	20'	Hw
3/14/81	20'	Hw
Total	80.0	Hw

Pulled casing 3/16/81
Progress Record

Depth	Date
0.0-20.0'	3/11/81
20.0-52.0'	3/12/81
52.0-77.4'	3/13/81
77.4-93.0'	3/14/81
93.0-140.0'	3/15/81

Completed 3/16/81
Hole Completion
3/16/81 Backfilled with cuttings and top 3.0' with cement.
Water Levels

Date	Depth
3/12/81	Dry to 17.0'
3/13/81	34.0'
3/14/81	41.0'
3/15/81	47.0'
3/16/81	54.0'

Water levels did not stabilize.

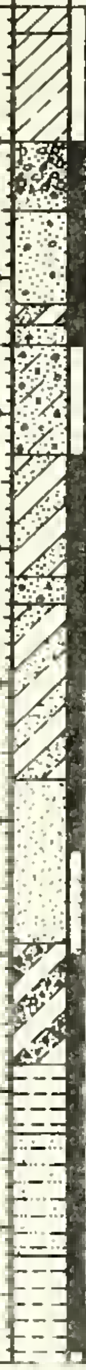
TYPE AND SIZE OF HOLE	CORE RECOVERY (%)
	90
Bx	60
	80
RB	wash
Hq	50
RB	wash
	5
	100
	42
Hq	15
RB	wash
	63
Hq	0
RB	wash
	36
	100
Hq	45

SOILS ANALYSIS SAMPLE	DEPTH (FEET) FROM	TO
#1	10.0	25.0
#2	33.0	57.0
#3	57.0 inus	78.0 62-70
#4	78.0	99.0

SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE — LIMITED SUITABILITY — UNSUITABLE

ELEVATION (FEET)	DEPTH (FEET)
2573.0	2.0
2565.0	10
2560.0	15.0
2550.0	25.0
2542.0	33.0
2533.0	42.0
2531.0	44.0
2518.0	57.0
2506.0	69.0
2497.0	78.0

GRAPHIC LOG



SAMPLES FOR TESTING

CLASSIFICATION AND PHYSICAL CONDITION

PLEISTOCENE(?)—EOLIAN
0.0-2.0' TOPSOIL: brown; moist; no HCl reaction; nonplasticity fines; top 1' is silt loam; roots to 1.5' (ML)
2.0-10.0' SANDY CLAYEY SILT: buff-tan; strong HCl reaction; crumbly; 95% nonplasticity fines; 5% very fine sand; core lengths are poor increasing to 5" below 5' as low plastic fines increase; sticky when wetted; shaves with knife. (ML) to (ML-CL)
2.0-3.5' Caliche zone with white traces of calcium carbonate.
PLEISTOCENE-CARTWRIGHT GRAVEL
10.0-15.0' GRAVELLY SAND: buff-tan; brown when moist; slight HCl reaction; 50% fine, hard, subangular gravel to ½"; 50% medium to coarse sand. (GP-SP)
14.0-15.0' gravel is absent.
15.0-25.0' SAND: tan; moist; no HCl reaction; 90% medium sand; 10% scattered fine, hard, subrounded gravel to 1½"; micaceous; poorly cemented. (SP)
22.0-23.5' Silty sand zone of 30% nonplasticity fines and 70% very fine sand. (SM)
25.0-33.0' GRAVELLY SAND: tan; moist; strong HCl reaction; 30% medium-sized, hard, subrounded to subangular gravel to 1½"; 60% very fine sand; 10% nonplasticity fines; core recovery was only 5%. (SP-SM)
33.0-42.0' SILTY SAND: tan; moist; strong HCl reaction; 35% slight plasticity fines; 65% fine sand; core lengths to 1½'; fair cohesion; crushes with fingers. (SM)
42.0-44.0' GRAVELLY SAND: tan; moist; strong HCl reaction; 80% fine sand; 20% medium-hard subangular gravel to 2". (SP)
44.0-57.0' SILTY SAND: tan; moist; strong HCl reaction; 65% fine sand; 35% slight plasticity fines; core lengths to 1'; fair cohesion. (SM-SC)
57.0-69.0' SAND: tan; moist; no HCl reaction; 95% fine uniform sand; 5% nonplasticity fines. (SP)
69.0-78.0' CLAYEY GRAVEL: tan; moist; strong HCl reaction; 60% fine; hard, subrounded gravel to 1½"; 20% low plasticity fines; 20% fine sand. (GC)
PALEOCENE-TONGUE RIVER MEMBER-FORT UNION FORMATION
78.0-101.7' SHALE: light gray; moist; slight HCl reaction; shaves with knife; low plasticity, bedding not discernible, core lenghts to 4"; few iron sulfide nodules.

EXPLANATION

▯ CORE LOSS
▮ CORE RECOVERY

Type of hole . . . . D = Diamond, H = Hayetollite, S = Shot, C = Churn
Hole sealed . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE S.W. Glendive PROJECT EMRIA STATE Montana SHEET 1 OF 2 HOLE NO. DH81-106

7-1337 (9-49)
Bureau of Reclamation
GPO 864-461

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

FEATURE S.W. Glendive PROJECT EMRIA STATE Montana
HOLE NO. DH81-106 LOCATION COORDS. 3.0' N. 620.0' W. of S.E. Corner Section 14; T15N., R53E. GROUND ELEV. 2575± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 3/11/81 FINISHED 3/16/81 DEPTH OF OVERBURDEN ——— TOTAL DEPTH 140.0' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Botdorf LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

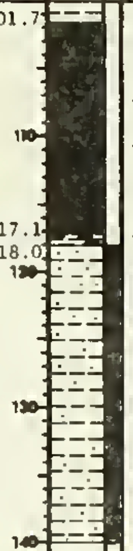
TYPE AND SIZE OF HOLE	CORE RECOVERY (%)
	100
Hq	80
	60
	71

SOILS ANALYSIS SAMPLE	DEPTH (FEET) FROM	TO
#5	118.0	130.0
#6	130.0	140.0

SUITABILITY FOR RECONSTRUCTED PROFILE: SUITABLE — LIMITED SUITABILITY — UNSUITABLE

ELEVATION (FEET)	DEPTH (FEET)
2473.3	101.7
Pause	
2457.9	117.1
2457.0	118.0
2435.0	140

GRAPHIC LOG



SAMPLES FOR TESTING

CLASSIFICATION AND PHYSICAL CONDITION

83.0-92.0' Sandy Siltstone— light grey; strong HCl reaction; about 35% fine uniform sand.
101.7-117.1' COAL: black; dry; platey breaks; core lengths to 2".
117.1-118.0' CARBONACEOUS SHALE: dark gray; moist; slight HCl reaction; hard; breaks along bedding plane; woody carbonized fragments; core lengths to 3".
118.0-140.0' SANDY SHALE: dark gray; moist; crumbly and knife leaves a dull sheen; low plasticity; strong HCl reaction; bedding is discernible, horizontal, and appears varved; about 25% fine sand 118.0-127.0 that decreases rapidly with depth.

EXPLANATION

▯ CORE LOSS
▮ CORE RECOVERY

Type of hole . . . . D = Diamond, H = Hayetollite, S = Shot, C = Churn
Hole sealed . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 5-3/8", Nx = 5"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-15/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE S.W. Glendive PROJECT EMRIA STATE Montana SHEET 2 OF 2 HOLE NO. DH81-106

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE AND POTENTIAL RECLAMATION EVALUATION
NORTHEAST MONTANA INVESTIGATIONS
SOUTHWEST GLENDIVE STUDY AREA—MONTANA

GEOLOGIC LOG OF DH 81-106

GEOLOGY C. BOTDORF FIELD APPROVAL
DRAWN TECHNICAL APPROVAL
CHECKED APPROVED
BILLINGS, MONTANA MAY 1983 1305-600-363

Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 2

FEATURE SW Glendive PROJECT EMRIA STATE Montana
HOLE NO. DH81-107 LOCATION 75' S. & 1990' W. of NE Corner Sec. 26, T. 15 N., R. 53 E. GROUND ELEV. 2600'± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 3-16-81 FINISHED 3-27-81 DEPTH OF OVERBURDEN ---- TOTAL DEPTH 159.0' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Drill
Failing 314 C truck-mounted.
Driller
R.V. Shaw
Method
Bx casing drive samples 0-25'. Rockbit (3-7/8") 25-96'. Driller could not obtain core samples in the gravel. Material was logged from wash samples and driller's report. 96-159' was cored with Hq wireline. Water used as drill fluid. Driller noted 50% water loss while drilling through gravel. No water loss while drilling in bedrock.
Casing Record
Set Hw to prevent caving and water loss. Pulled all casing on completion of hole.

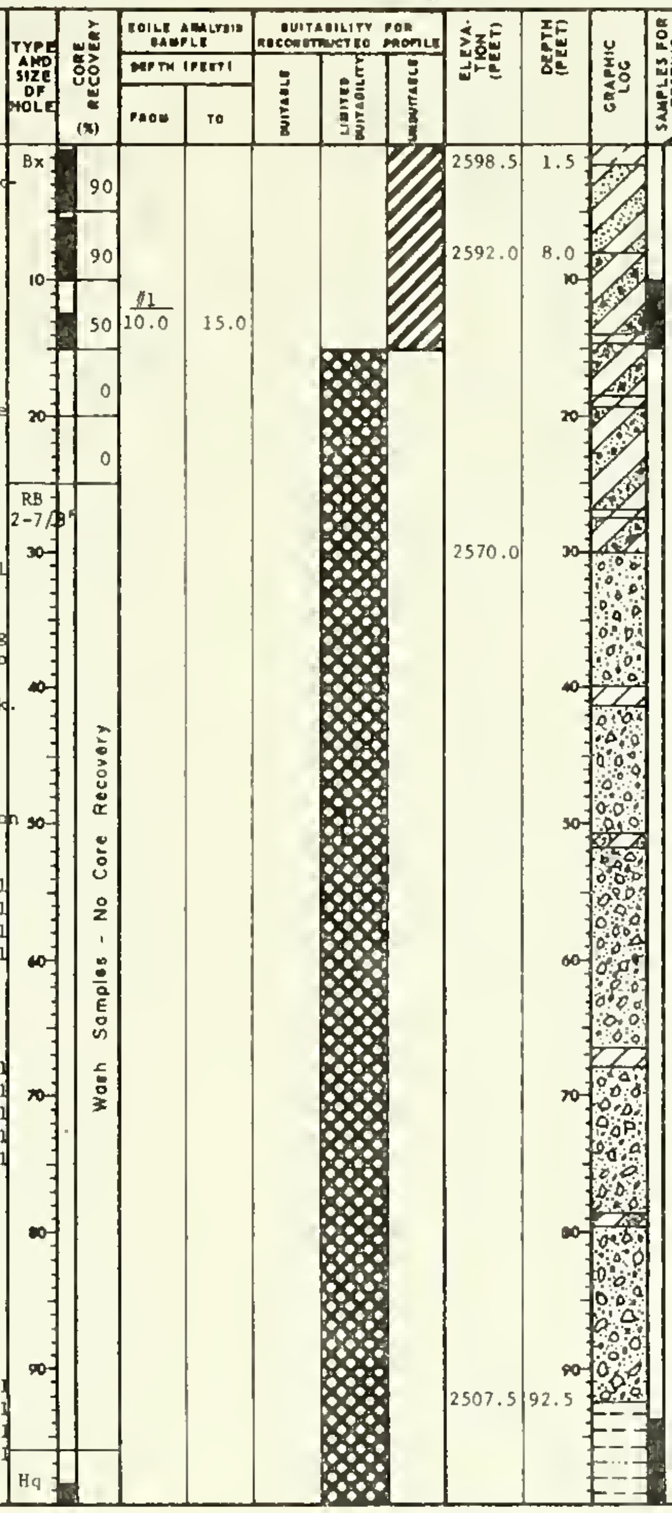
Depth	Date
0-20.5'	3-16-81
20.5-70.5'	3-17-81
70.5-90.5'	3-18-81
90.5-95.5'	3-25-81

Casing pulled 3-26 and 3-27-81.
Progress Record

Depth	Date
0-20'	3-16-81
20-69'	3-17-81
69-92.5'	3-18-81
92.5-129'	3-25-81
129-159'	3-26-81

Finished pulling casing 3-27-81.
Hole Completion
Pulled casing and backfilled hole 3-27-81.
Water Levels
Not stabilized.

Depth	Date
Dry to 20'	3-17-81
Dry to 69'	3-18-81
Dry to 90'	3-25-81
90'	3-26-81



CLASSIFICATION AND PHYSICAL CONDITION

PLEISTOCENE (?)-EOLIAN
0-1.5' TOPSOIL: approx. 80% very low plasticity fines; 20% very fine sand; dry; crumbly; brown; strong HCl reaction; scattered grass roots. (ML-CL)
1.5-8.0' SILTY SAND: approx. 60% very fine sand; 40% nonplastic fines; dry loose; tan; strong HCl reaction. (SM)
PLEISTOCENE-CARTWRIGHT GRAVEL
8.0-30.0' SILTY SAND: poor recovery--mostly wash samples; approx. 80% mostly fine sand; 20% nonplastic fines; scattered small gravels to ½"; occasional thin silt layers and very silty sand zones; dry to moist; light brown; strong grading to weak HCl reaction. (SM) with layers of (ML).
30.0-92.5' GRAVEL: logged from wash samples--could not hold gravel in core barrel; approx. 70% fine to coarse gravel; 30% fine to coarse sand; scattered cobbles; occasional silt or silty sand layers from 1' to 2' thick between 38.2 and 69' (drill report); brown; loose; no HCl reaction. (GP)
PALEOCENE-TONGUE RIVER MEMBER-FORT UNION FORMATION
92.5-118.7' SILTY SHALE: light to medium gray; firm; cuts easily with knife; moist; strong HCl reaction; bedding nearly horizontal; core lengths to 18".
Carbonaceous zones at 105.5-105.8'; 114.6-115.0' and 118.0-118.3'.
118.7-134.1' COAL: black; wet; brittle.
134.1-159.0' SILTY SHALE: light to medium gray; moist; firm; cuts easily; scattered pyrite nodules to 1¼"; strong HCl reaction; bedding nearly horizontal; core lengths to 20".
135.3-137.0' Coal-black; wet; brittle.

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . . . D = Diamond, N = Hoystellite, S = Shot, C = Churn
Hole sealed . . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE SW Glendive PROJECT EMRIA STATE Montana SHEET 1 OF 2 HOLE NO. DH81-107

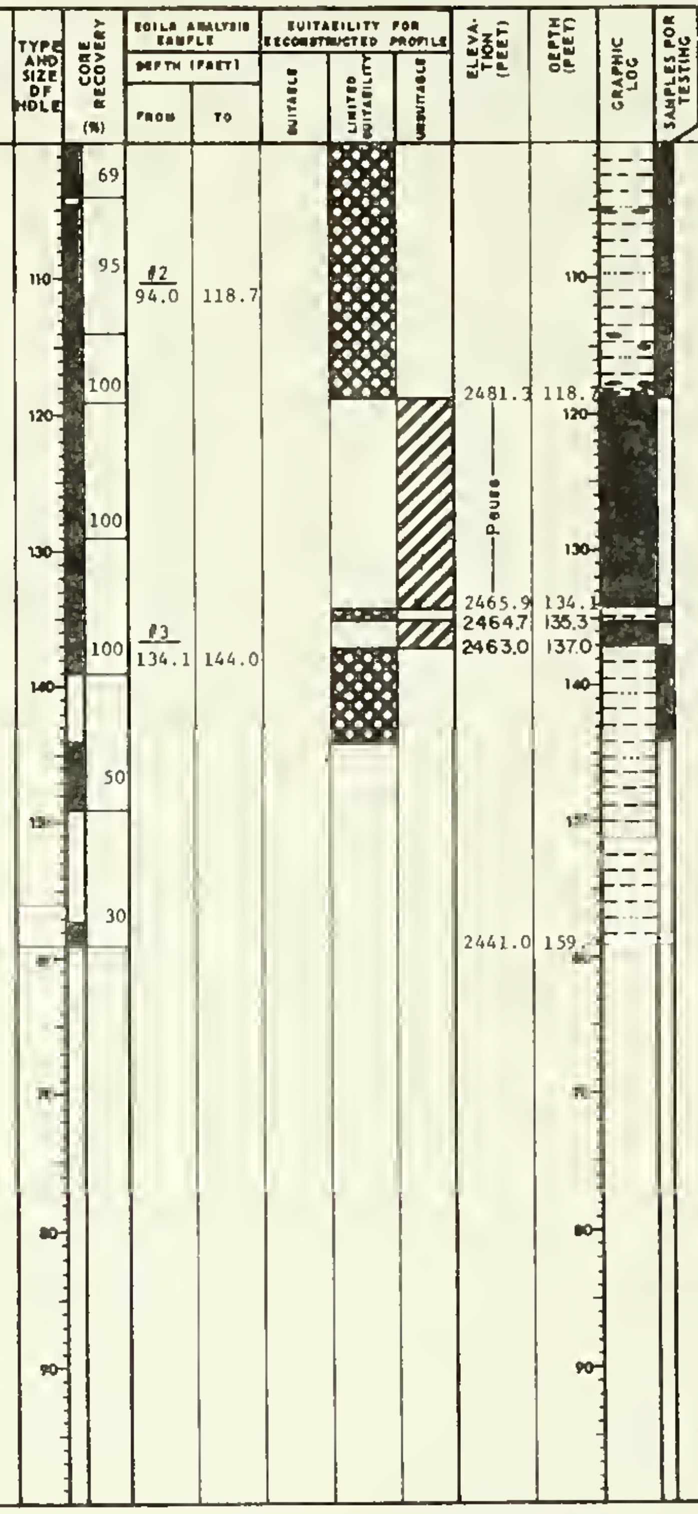
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 2

FEATURE SW Glendive PROJECT EMRIA STATE Montana
HOLE NO. DH81-107 LOCATION 75' S. & 1990' W. of NE Corner Sec. 26, T. 15 N., R. 53 E. GROUND ELEV. 2600± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 3-16-81 FINISHED 3-27-81 DEPTH OF OVERBURDEN ---- TOTAL DEPTH 159.0' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS



CLASSIFICATION AND PHYSICAL CONDITION

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole . . . . . D = Diamond, N = Hoystellite, S = Shot, C = Churn
Hole sealed . . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE SW Glendive PROJECT EMRIA STATE Montana SHEET 2 OF 2 HOLE NO. DH81-107

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE AND POTENTIAL RECLAMATION EVALUATION

NORTHEAST MONTANA INVESTIGATIONS
SOUTHWEST GLENDIVE STUDY AREA-MONTANA

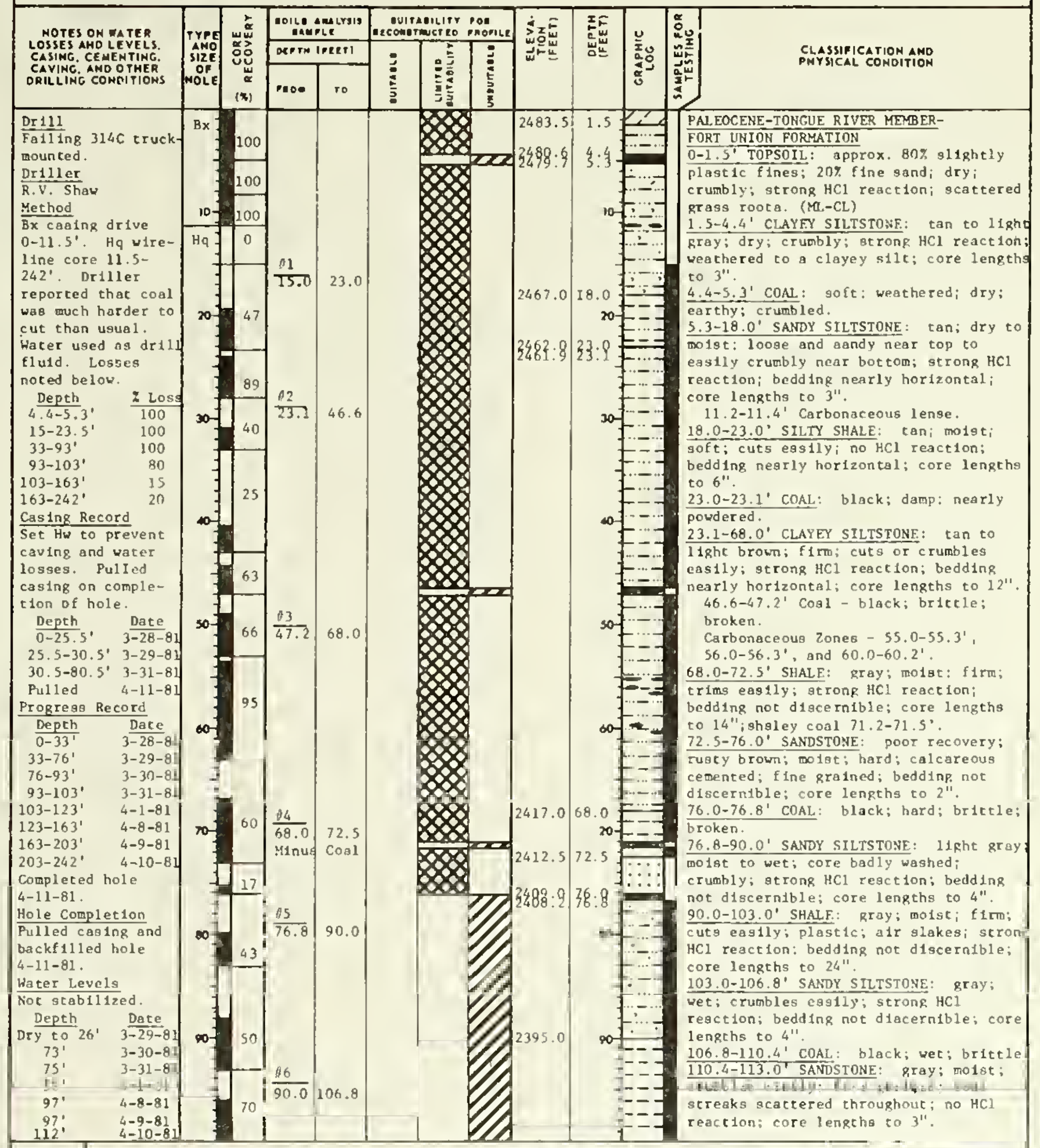
GEOLOGIC LOG OF DH 81-107

GEOLOGY L. PARISH FIELD APPROVAL
DRAWN TECHNICAL APPROVAL
CHECKED APPROVED
BILLINGS, MONTANA MAY 1983 1305-600-364

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

FEATURE Circle 2 PROJECT EMRIA STATE Montana
HOLE NO DH81-108 LOCATION 790' S. & 1580' E. of NW Corner Sec. 26, T. 20 N., R. 49E GROUND ELEV. 2485'± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 3-28-81 FINISHED 4-11-81 DEPTH OF OVERBURDEN ---- TOTAL DEPTH 242.0' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY


NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS
TYPE AND SIZE OF HOLE
CORE RECOVERY (%)
SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM TO
SUITABILITY FOR RECONSTRUCTED PROFILE
SUITABLE
LIMITED SUITABILITY
UNSUITABLE
ELEVATION (FEET)
DEPTH (FEET)
GRAPHIC LOG
SAMPLES FOR TESTING
CLASSIFICATION AND PHYSICAL CONDITION
Bx
Hq
10
20
30
40
50
60
70
80
90

Drill
Failing 314C truck-mounted.

Driller
R.V. Shaw

Method
Bx casing drive 0-11.5'. Hq wire-line core 11.5-242'. Driller reported that coal was much harder to cut than usual. Water used as drill fluid. Losses noted below.

Depth	% Loss
4.4-5.3'	100
15-23.5'	100
33-93'	100
93-103'	80
103-163'	15
163-242'	20

Casing Record
Set Hw to prevent caving and water losses. Pulled casing on completion of hole.

Depth	Date
0-25.5'	3-28-81
25.5-30.5'	3-29-81
30.5-80.5'	3-31-81
Pulled	4-11-81

Progress Record

Depth	Date
0-33'	3-28-81
33-76'	3-29-81
76-93'	3-30-81
93-103'	3-31-81
103-123'	4-1-81
123-163'	4-8-81
163-203'	4-9-81
203-242'	4-10-81

Completed hole 4-11-81.

Hole Completion
Pulled casing and backfilled hole 4-11-81.

Water Levels
Not stabilized.

Depth	Date
Dry to 26'	3-29-81
73'	3-30-81
75'	3-31-81
[illegible]	[illegible]
97'	4-8-81
97'	4-9-81
112'	4-10-81

Core recovery (%): 100, 100, 100, 0, 47, 89, 40, 25, 63, 66, 95, 60, 17, 43, 50, 70

Sample	From	To
#1	15.0	23.0
#2	23.1	46.6
#3	47.2	68.0
#4	68.0 Minus	72.5 Coal
#5	76.8	90.0
#6	90.0	106.8

Elevation (feet)	Depth (feet)
2483.5	1.5
2480.6	4.4
2479.7	5.3
2467.0	18.0
2462.0	23.0
2461.9	23.1
2417.0	68.0
2412.5	72.5
2409.0	76.0
2408.2	76.8
2395.0	

PALEOCENE-TONGUE RIVER MEMBER-FORT UNION FORMATION

0-1.5' TOPSOIL: approx. 80% slightly plastic fines; 20% fine sand; dry; crumbly; strong HCl reaction; scattered grass roots. (ML-CL)

1.5-4.4' CLAYEY SILTSTONE: tan to light gray; dry; crumbly; strong HCl reaction; weathered to a clayey silt; core lengths to 3".

4.4-5.3' COAL: soft; weathered; dry; earthy; crumbled.

5.3-18.0' SANDY SILTSTONE: tan; dry to moist; loose and sandy near top to easily crumbly near bottom; strong HCl reaction; bedding nearly horizontal; core lengths to 3".
11.2-11.4' Carbonaceous lense.

18.0-23.0' SILTY SHALE: tan; moist; soft; cuts easily; no HCl reaction; bedding nearly horizontal; core lengths to 6".

23.0-23.1' COAL: black; damp; nearly powdered.

23.1-68.0' CLAYEY SILTSTONE: tan to light brown; firm; cuts or crumbles easily; strong HCl reaction; bedding nearly horizontal; core lengths to 12".
46.6-47.2' Coal - black; brittle; broken.
Carbonaceous Zones - 55.0-55.3', 56.0-56.3', and 60.0-60.2'.

68.0-72.5' SHALE: gray; moist; firm; trims easily; strong HCl reaction; bedding not discernible; core lengths to 14"; shaley coal 71.2-71.5'.

72.5-76.0' SANDSTONE: poor recovery; rusty brown; moist; hard; calcareous cemented; fine grained; bedding not discernible; core lengths to 2".

76.0-76.8' COAL: black; hard; brittle; broken.

76.8-90.0' SANDY SILTSTONE: light gray; moist to wet; core badly washed; crumbly; strong HCl reaction; bedding not discernible; core lengths to 4".

90.0-103.0' SHALE: gray; moist; firm; cuts easily; plastic; air slakes; strong HCl reaction; bedding not discernible; core lengths to 24".

103.0-106.8' SANDY SILTSTONE: gray; wet; crumbles easily; strong HCl reaction; bedding not discernible; core lengths to 4".

106.8-110.4' COAL: black; wet; brittle.

110.4-113.0' SANDSTONE: gray; moist; crumbles easily; fine grained; coal streaks scattered throughout; no HCl reaction; core lengths to 3".

EXPLANATION

▯ CORE LOSS
■ CORE RECOVERY

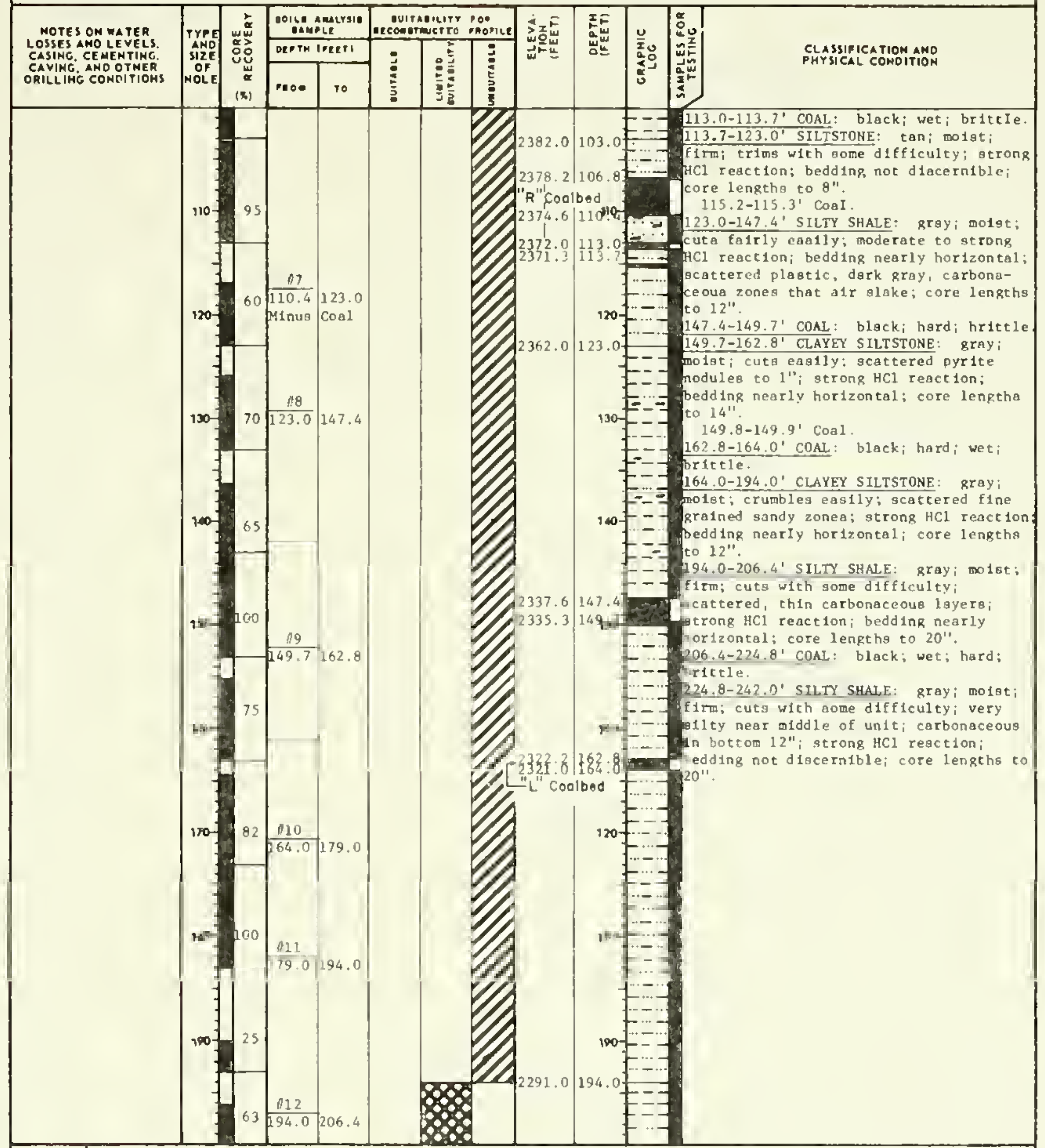
Type of hole . . . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Circle 2 PROJECT EMRIA STATE Montana SHEET 1 OF 3 HOLE NO. DH81-108

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

FEATURE Circle 2 PROJECT EMRIA STATE Montana
HOLE NO. DH81-108 LOCATION 790' S. & 1580' E. of NW Corner Sec. 26, T. 20 N., R. 49 E. GROUND ELEV. 2485'± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 3-28-81 FINISHED 4-11-81 DEPTH OF OVERBURDEN ---- TOTAL DEPTH 242.0' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY


NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS
TYPE AND SIZE OF HOLE
CORE RECOVERY (%)
SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM TO
SUITABILITY FOR RECONSTRUCTED PROFILE
SUITABLE
LIMITED SUITABILITY
UNSUITABLE
ELEVATION (FEET)
DEPTH (FEET)
GRAPHIC LOG
SAMPLES FOR TESTING
CLASSIFICATION AND PHYSICAL CONDITION
110
120
130
140
170
190
"R" Coalbed
"L" Coalbed

Core recovery (%): 95, 60, 70, 65, 100, 75, 82, 100, 25, 63

Sample	From	To
#7	110.4 Minus	123.0 Coal
#8	123.0	147.4
#9	149.7	162.8
#10	164.0	179.0
#11	179.0	194.0
#12	194.0	206.4

Elevation (feet)	Depth (feet)
2382.0	103.0
2378.2	106.8
2374.6	110.4
2372.0	113.0
2371.3	113.7
2362.0	123.0
2337.6	147.4
2335.3	149.7
2322.2	162.8
2321.0	164.0
2291.0	194.0

113.0-113.7' COAL: black; wet; brittle.

113.7-123.0' SILTSTONE: tan; moist; firm; trims with some difficulty; strong HCl reaction; bedding not discernible; core lengths to 8".
115.2-115.3' Coal.

123.0-147.4' SILTY SHALE: gray; moist; cuts fairly easily; moderate to strong HCl reaction; bedding nearly horizontal; scattered plastic, dark gray, carbonaceous zones that air slake; core lengths to 12".

147.4-149.7' COAL: black; hard; brittle.

149.7-162.8' CLAYEY SILTSTONE: gray; moist; cuts easily; scattered pyrite nodules to 1"; strong HCl reaction; bedding nearly horizontal; core lengths to 14".
149.8-149.9' Coal.

162.8-164.0' COAL: black; hard; wet; brittle.

164.0-194.0' CLAYEY SILTSTONE: gray; moist; crumbles easily; scattered fine grained sandy zones; strong HCl reaction; bedding nearly horizontal; core lengths to 12".

194.0-206.4' SILTY SHALE: gray; moist; firm; cuts with some difficulty; scattered, thin carbonaceous layers; strong HCl reaction; bedding nearly horizontal; core lengths to 20".

206.4-224.8' COAL: black; wet; hard; brittle.

224.8-242.0' SILTY SHALE: gray; moist; firm; cuts with some difficulty; very silty near middle of unit; carbonaceous in bottom 12"; strong HCl reaction; bedding not discernible; core lengths to 20".

EXPLANATION

▯ CORE LOSS
■ CORE RECOVERY

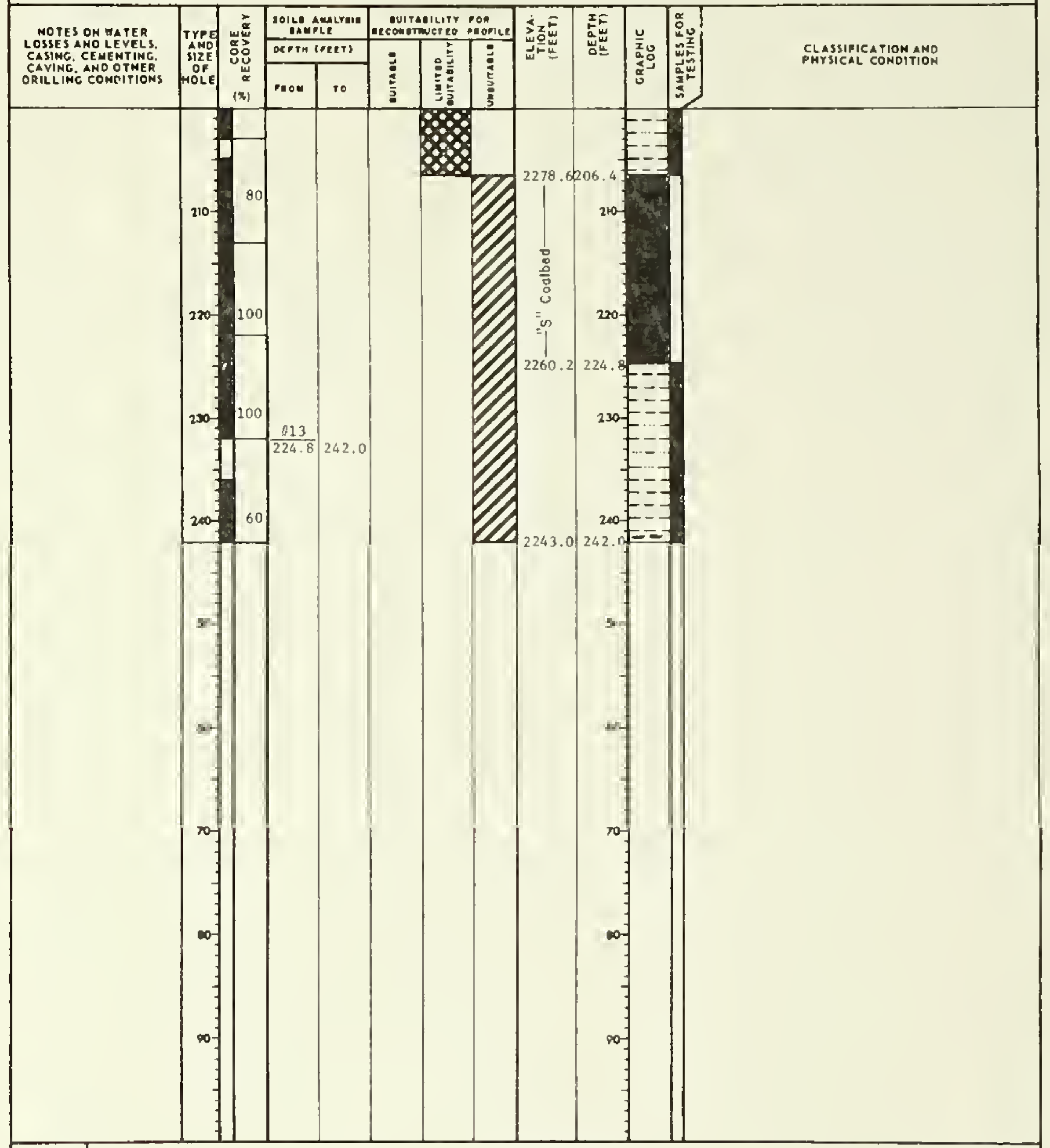
Type of hole . . . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Circle 2 PROJECT EMRIA STATE Montana SHEET 2 OF 3 HOLE NO. DH81-108

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

FEATURE Circle 2 PROJECT EMRIA STATE Montana
HOLE NO. DH81-108 LOCATION 790' S. & 1580' E. of NW Corner Sec. 26, T. 20 N., R. 49 E. GROUND ELEV 2485'± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 3-28-81 FINISHED 4-11-81 DEPTH OF OVERBURDEN ---- TOTAL DEPTH 242.0' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY


NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS
TYPE AND SIZE OF HOLE
CORE RECOVERY (%)
SOILS ANALYSIS SAMPLE DEPTH (FEET) FROM TO
SUITABILITY FOR RECONSTRUCTED PROFILE
SUITABLE
LIMITED SUITABILITY
UNSUITABLE
ELEVATION (FEET)
DEPTH (FEET)
GRAPHIC LOG
SAMPLES FOR TESTING
CLASSIFICATION AND PHYSICAL CONDITION
210
220
230
240
"S" Coalbed

Core recovery (%): 80, 100, 100, 60

Sample	From	To
#13	224.8	242.0

Elevation (feet)	Depth (feet)
2278.6	206.4
2260.2	224.8
2243.0	242.0

EXPLANATION

▯ CORE LOSS
■ CORE RECOVERY

Type of hole . . . . . D = Diamond, H = Hoystellite, S = Shot, C = Churn
Hole sealed . . . . . P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) . . Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) . . Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series) . . Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) . . Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

FEATURE Circle 2 PROJECT EMRIA STATE Montana SHEET 3 OF 3 HOLE NO. DH81-108

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE AND POTENTIAL RECLAMATION EVALUATION
NORTHEAST MONTANA INVESTIGATIONS
CIRCLE 2 STUDY AREA-MONTANA

GEOLOGIC LOG OF DH 81-108

GEOLOGY L. PARISH FIELD APPROVAL
DRAWN TECHNICAL APPROVAL
CHECKED APPROVED
BILLINGS, MONTANA MAY 1983 1305-600-365

Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 1 OF 3

FEATURE Circle 2 PROJECT EMRIA STATE Montana
HOLE NO. DH81-109 LOCATION 1550' S. & 25' E. of NW Corner Sec. 4, T. 20 N., R. 49 E. GROUND ELEV. 2475'± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 4-12-81 FINISHED 4-23-81 DEPTH OF OVERBURDEN ---- TOTAL DEPTH 244.0' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS

Drill
Failing 314C truck-mounted.
Driller
R.V. Shaw
Method
Bx casing drive 0-13'. Hq wireline core 13-244'. Water used as drill fluid. Water losses during drilling noted below.

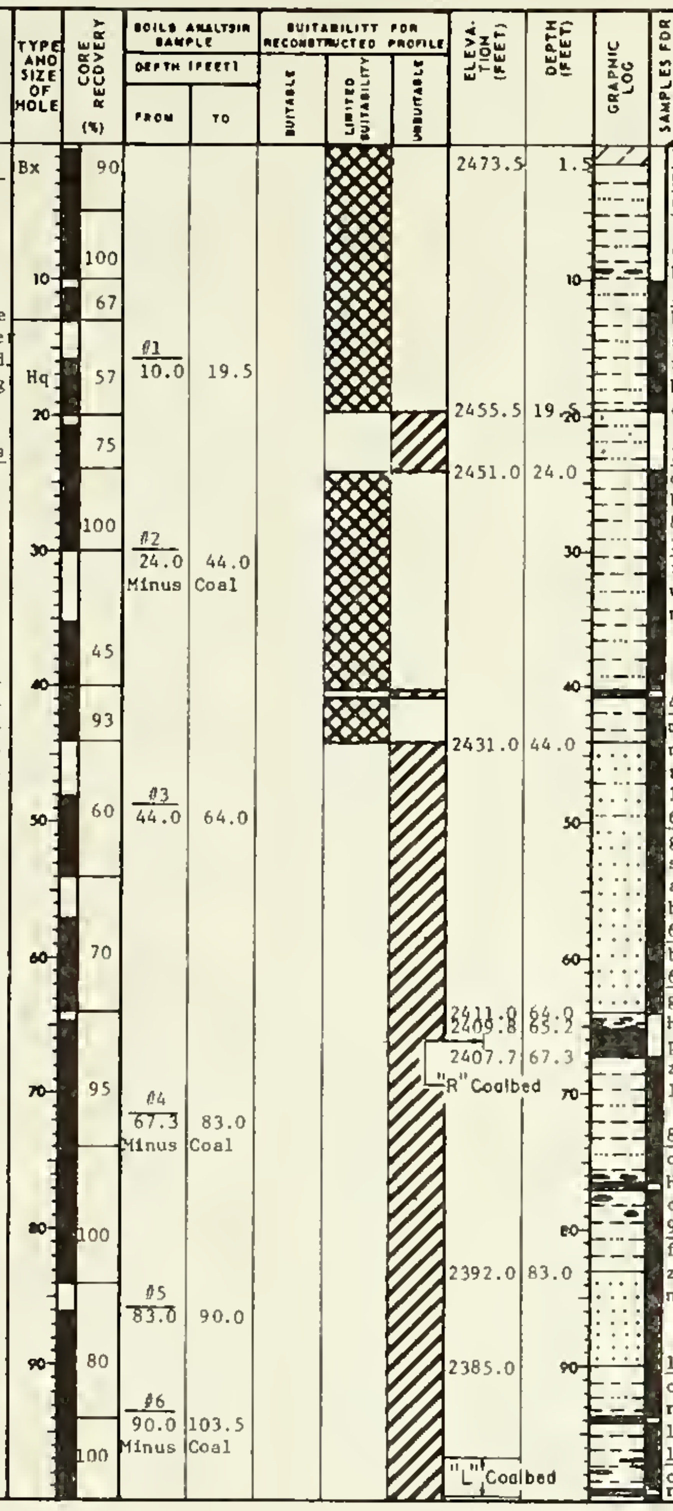
Depth	% Loss
0-154'	0
154-244'	20

Casing Record
Set 10.0' of Hw 4-12-81 to prevent surface caving. Pulled 4-23-81.
Progress Record

Depth	Date
0-30'	4-12-81
30-94'	4-13-81
94-154'	4-14-81
154-204'	4-15-81
204-244'	4-22-81

Completed hole 4-23-81.
Hole Completion
Pulled casing and backfilled hole 4-23-81.
Water Levels
Not stabilized.

Depth	Date
11.0'	4-13-81
34.0'	4-14-81
79.0'	4-15-81
91.0'	4-22-81



Sample	From	To
#1	10.0	19.5
#2	24.0 Minus	44.0 Coal
#3	44.0	64.0
#4	67.3 Minus	83.0 Coal
#5	83.0	90.0
#6	90.0 Minus	103.5 Coal

Elevation (feet)	Depth (feet)
2473.5	1.5
2455.5	19.5
2451.0	24.0
2431.0	44.0
2411.0	64.0
2409.8	65.2
2407.7	67.3
2392.0	83.0
2385.0	

CLASSIFICATION AND PHYSICAL CONDITION

PALEOCENE-TONGUE RIVER MEMBER-FORT UNION FORMATION

0-1.5' TOPSOIL: approx. 80% very low plasticity fines; 20% fine sand; brown; crumbly; scattered grass roots; strong HCl reaction. (CL)

1.5-19.5' SILTY SHALE: tan to light brown; damp; crumbly; very silty, with scattered zones of siltstone; strong HCl reaction except 4 to 5', which has no HCl reaction; bedding not discernible; core lengths to 2".
9.0-9.1' Carbonaceous layer.

19.5-24.0' SANDY SILTSTONE: light gray; dry; very hard; calcareous cemented; bedding not discernible; core lengths to 8".

24.0-44.0' SILTY SHALE: light brown to rusty brown; moist; firm; cuts easily; weak to strong HCl reaction; bedding nearly horizontal; core lengths to 12".
Carbonaceous zones - 24.4-24.6', 28.0-30.0' and 39.5-40.2'.
40.2-40.5' Coal.

44.0-64.0' SANDSTONE: light brown; moist to wet; loose to crumbly; silty near top; fine grained; strong HCl reaction; bedding not discernible; core lengths to 6".

64.0-65.2' CARBONACEOUS SHALE: dark gray; moist; firm; cuts with difficulty; several ¼" thick coal beds; plastic; air slakes; no HCl reaction; bedding nearly horizontal; core lengths to 6".

65.2-67.3' COAL: black; wet; brittle; broken.

67.3-83.0' SILTY SHALE: medium to dark gray; moist; firm; cuts easily; moderate HCl reaction; carbonaceous 75.5-78.0'; plastic and air slakes in carbonaceous zone; bedding nearly horizontal; core lengths to 18".
76.5-76.9' Coal.

83.0-90.0' SANDSTONE: gray; wet; crumbly to loose; fine grained; strong HCl reaction; bedding not discernible; core lengths to 4".

90.0-103.5' SILTY SHALE: gray; moist; firm; cuts easily; air slakes in plastic zones; strong HCl reaction; bedding nearly horizontal; core lengths to 16".
Coal - 93.7-94.0' and 99.3-99.6'.
97.0-97.3' Carbonaceous layer.

103.5-115.0' SANDSTONE: gray; wet; crumbles easily; fine grained; strong HCl reaction; bedding not discernible; core lengths to 14".

115.0-137.7' SHALE: gray; moist; firm; cuts with some difficulty; strong HCl reaction; bedding not discernible; core

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

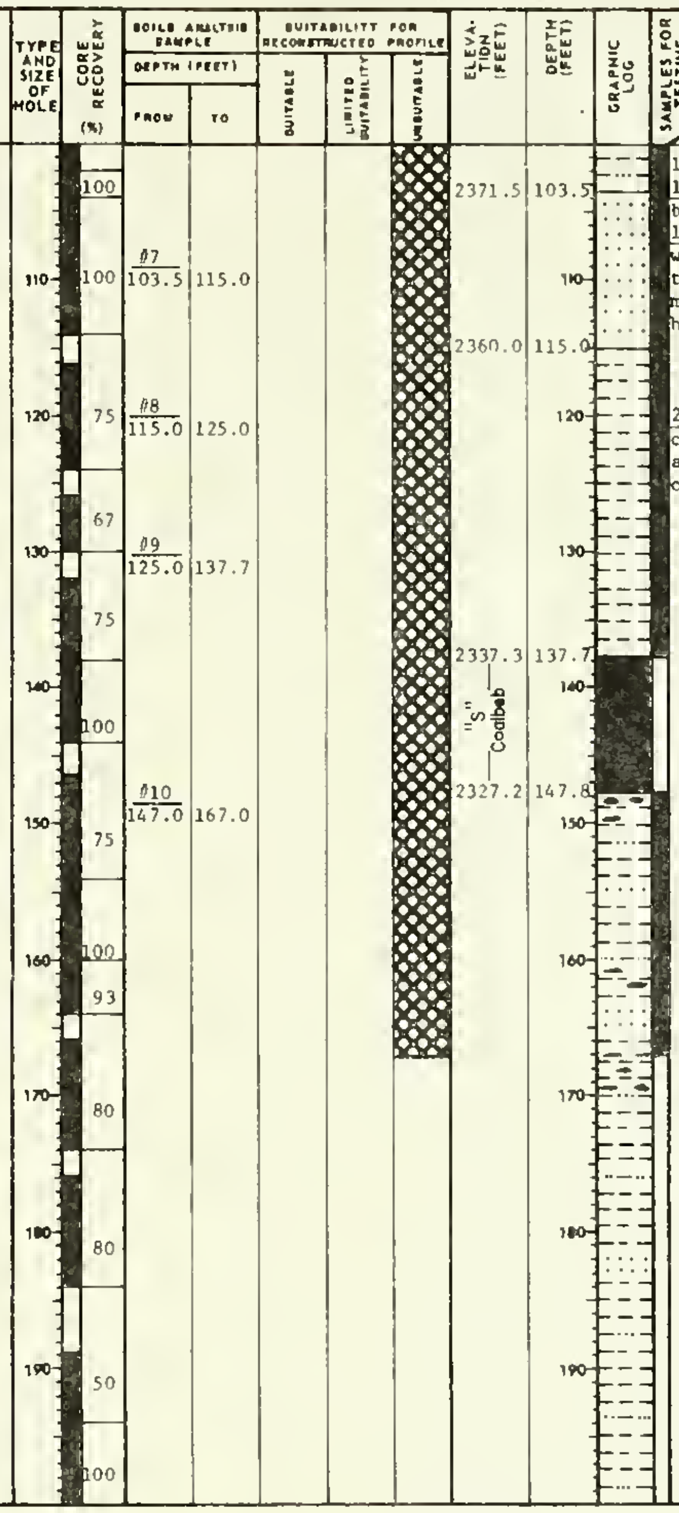
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 2 OF 3

FEATURE Circle 2 PROJECT EMRIA STATE Montana
HOLE NO. DH81-109 LOCATION 1550' S. & 25' E. of NW Corner Sec. 4, T. 20 N., R. 49 E. GROUND ELEV. 2475'± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 4-12-81 FINISHED 4-23-81 DEPTH OF OVERBURDEN ---- TOTAL DEPTH 244.0' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS



Sample	From	To
#7	103.5	115.0
#8	115.0	125.0
#9	125.0	137.7
#10	147.0	167.0

Elevation (feet)	Depth (feet)
2371.5	103.5
2360.0	115.0
2337.3	137.7
2327.2	147.8

CLASSIFICATION AND PHYSICAL CONDITION

lengths to 18".

137.7-147.8' COAL: black; wet; brittle; broken.

147.8-228.0' SILTY SHALE: gray; moist to wet; firm; cuts easily; scattered 1 to 2" thick silty sandstone layers; weak to moderate HCl reaction; bedding nearly horizontal; core lengths to 24".
Carbonaceous zones - 147.8-150.0', 161.5-162.0', 167.0-170.0', and 220.0-223.0'.

228.0-244.0' SANDSTONE: gray; wet; uncemented; crumbles easily; fine grained; strong HCl reaction; bedding not discernible; core lengths to 12".

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

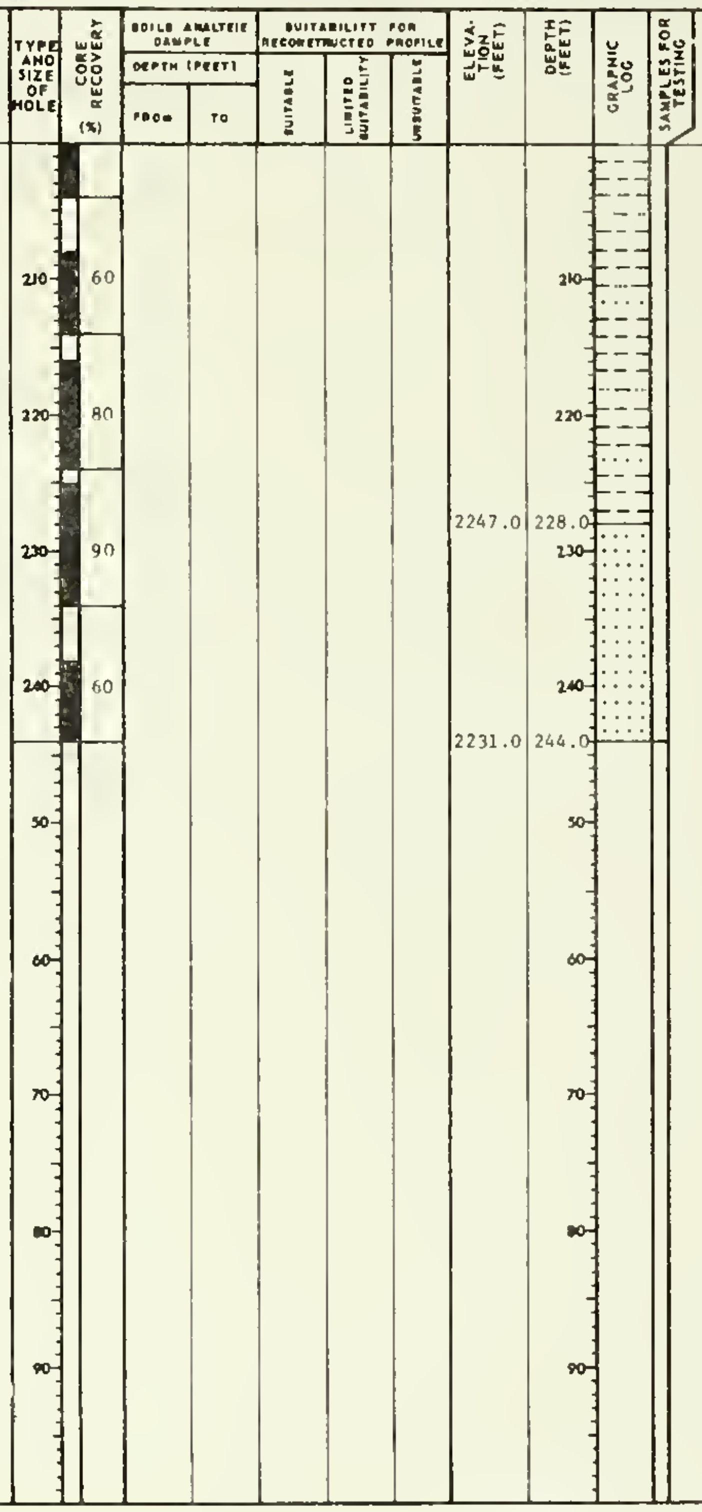
Bureau of Reclamation

GEOLOGIC LOG OF DRILL HOLE

SHEET 3 OF 3

FEATURE Circle 2 PROJECT EMRIA STATE Montana
HOLE NO. DH81-109 LOCATION 1550' S. & 25' E. of NW Corner Sec. 4, T. 20 N., R. 49 E. GROUND ELEV. 2475'± DIP (ANGLE FROM HORIZ.) Vertical
BEGUN 4-12-81 FINISHED 4-23-81 DEPTH OF OVERBURDEN ---- TOTAL DEPTH 244.0' BEARING
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED See Notes LOGGED BY Parish LOG REVIEWED BY

NOTES ON WATER LOSSES AND LEVELS, CASING, CEMENTING, CAVING, AND OTHER DRILLING CONDITIONS



Elevation (feet)	Depth (feet)
2247.0	228.0
2231.0	244.0

CLASSIFICATION AND PHYSICAL CONDITION

EXPLANATION

CORE LOSS
CORE RECOVERY

Type of hole .... D = Diamond, H = Haystellite, S = Shot, C = Churn
Hole sealed .... P = Packer, Cm = Cemented, Cs = Bottom of casing
Approx. size of hole (X-series) .. Ex = 1-1/2", Ax = 1-7/8", Bx = 2-3/8", Nx = 3"
Approx. size of core (X-series) .. Ex = 7/8", Ax = 1-1/8", Bx = 1-5/8", Nx = 2-1/8"
Outside dia. of casing (X-series). Ex = 1-13/16", Ax = 2-1/4", Bx = 2-7/8", Nx = 3-1/2"
Inside dia. of casing (X-series) .. Ex = 1-1/2", Ax = 1-29/32", Bx = 2-3/8", Nx = 3"

Depth on logs in feet.
Multiply feet by 0.3048 to obtain meters.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE AND POTENTIAL RECLAMATION EVALUATION
NORTHEAST MONTANA INVESTIGATIONS
CIRCLE 2 STUDY AREA-MONTANA

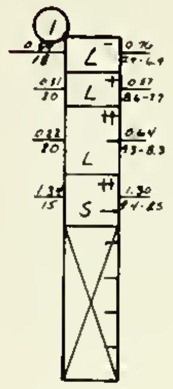
GEOLOGIC LOG OF DH 81-109

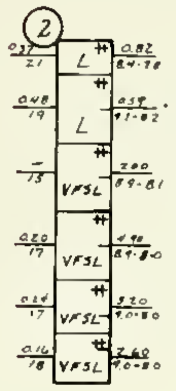
GEOLOGY L. PARISH FIELD APPROVAL
DRAWN TECHNICAL APPROVAL
CHECKED APPROVED
BILLINGS, MONTANA MAY 1983 1305-600-366

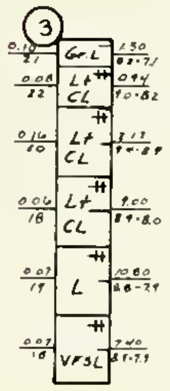
APPENDIX C

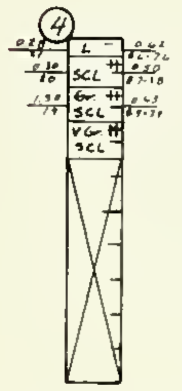
SOIL AND OVERBURDEN

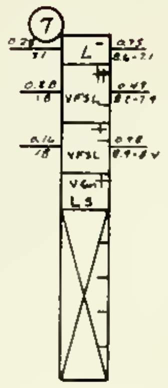
Sec. 14, T15N-R53E

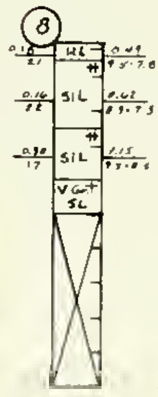

250'N., 150' W. of SE Corner. 2-4%, complex-fill area (alluvium). Very gravelly/cobbly SL occurs below 32-48" in much of unit. Profile - Ap-0-6", B2-6-17", B3ca-17-24", C1ca-24-33", C2-33-48", IIC-48"+ 24-48" zone: SAR = 1.34; Gyp. Req. = +3.12; Lab texture-L. Small grains.

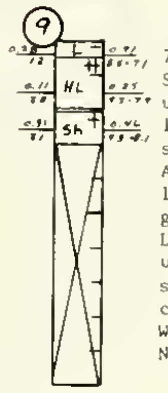

750' N. 1450' W. of SE Corner. 4-8%, complex, soil developing in old alluvium. Profile-Ap-0-6", B2-6-9", B3ca-9-12", C1ca-12-36", C2-36+. About 5% gravel in 0-6" zone. Scattered gravel/cobble on surface. 36-60" zone: Gyp. Req. = +1.17; Lab texture-SiL. Small grains.

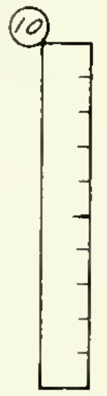

800' S., 550' W. of E½. 0-8% complex soil developing in old alluvium. 47% gravel in surface 10" (lab). 10-25% gravel/cobble on surface. Profile-Ap-0-5", weak B2-5-10", B3=10=14", C1ca-14-24", C2-24-72", C3-72-96, C4-96-120". 48-72" zone: Gyp. Req. = +2.24, Lab texture-CL.

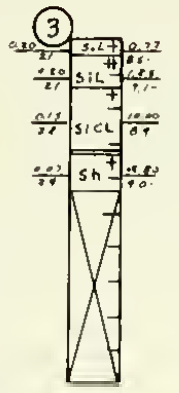

1550' S., 1550' W. of NE Corner. 2-4% complex sideslope along Whoopup Creek drainage. Old alluvium. 56% gravel in 18-30" zone (lab). Unable to penetrate>30" due to gravel/cobble. A1-0-3", B1-3-8", B3-8-11", C1ca-11-18", C2-18-30"+. Western wheat grass, Blue grama.

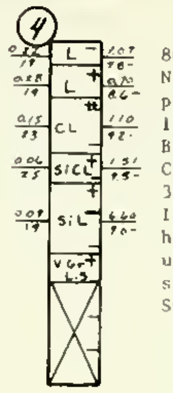

325' N., 1375' E. of W¼. 4-8% complex old alluvium. Profile: Ap-0-6", B2-6-10", B3ca-10-17", C1ca-17-30", C2-30-48", IIC-48"+. Depth to sand & gravel ranges from 30-54". Local highs in unit have40-50% surface gravel/cobble. Small grains

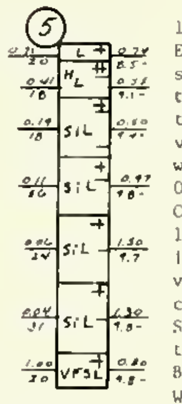

725' N., 975' E. of SW Corner. 4-8% complex; old alluvium. Profile - Ap-0-5", B2-5-7", B3ca-7-15", C1ca-15-30", C2-30-48", IIC-48"+ About 5% gravel in soil mass. Scattered surface gravel/cobble- highs have 30-40% surface rock. 0-7" zone: SAR = 0.18; Gyp. Req. = + 2.76; Lab texture-SiL. Small grains.

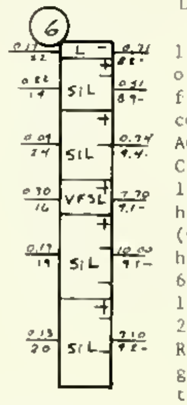

750' N., 125' W of S¼. 12-20% complex; uplands-thin alluvial cap overlying silty shale. A1-0-3", AC-3-6", C1ca-6-24", IIC-24-36"+. 5-10% gravel in 0-24" zone. Localized highs in unit have 30-40% surface gravel/cobble. Range - Western wheatgrass, Needleandthread.

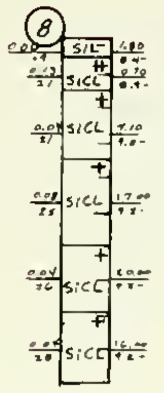

500' S., 1300' E. of W¼. Refer to Point Site #10 for profile description and laboratory data. (Appendix).

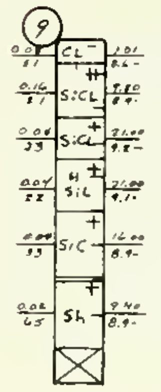

1000' N., 800' W. of E¼. 6-15% complex footslope (alluvial/colluvial) 39"+ - clayey shale place below root zone. Depth to shale ranges from 32-44" in unit. Ap-0-5", C1ca-5-18", C2-18-39", IIC-39"+. 39"+: SAR = 1.34; Gyp. Req. = +0.40; Lab texture - SiCL. Small grains.

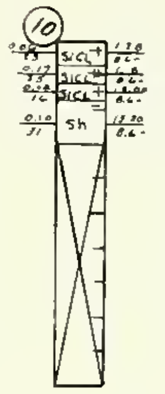

800' S., 200' W. of NE Corner. 4-8% complex, ancient alluvial terrace. Ap-0-6", B2-6-9", B3-9-20", C1ca-20-39", C2-39-50", C3-50-74", IIC-74"+. Local highs(ridges) in unit have 35-50% surface gravel. Small grains.

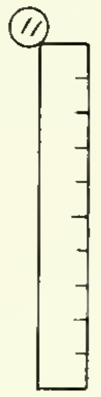

150' S., 575' W. of E¼. 8-15% complex-some slopes adjacent to eroded outcrops to 40%. Soil developing in local wash (alluvium) A1-0-2", C1ca-2-18", C2-18-108", C3-108-120"+. Eroded highs in unit have a thin veneer of gravel/cobble. 42-60" zone: SAR = 9.1; Lab texture - L. Range-Bluebunch wheatgrass, Western wheatgrass, Little bluestem.


1150' N., 825' E of S¼. 2-6% complex fill area (alluvial/colluvial). A1-0-3", AC-3-5", C1-4-48", C2-48-60", C3-60-120". Surface 6" has 5-10% gravel (washed down from hills to the east). 60-90" zone: SAR = 1.0; Gyp. Req. = + 2.0; Lab texture L. Range-Western wheatgrass, Needleandthread.

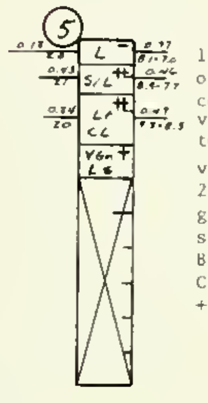

700' N., 425' E. of W¼. 0-4%, complex, fill area (alluvial/colluvial). Ap-0-5", C1-5-9", C2ca-9-18", C3-18-120". 72-96" zone: SAR = 8.6; Gyp. Req. = +1.0; Lab texture-SiL. Small grains.

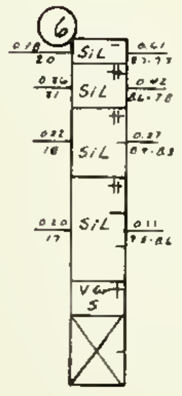

500' N., 600' W. of S¼. 0-4% complex, fill area (alluvial/colluvial) over shale. Ap-0-6", AC-6-8", C1ca-8-27", C2-27-42", C3-42-60", C4-60-84", IIC-84"+ - weathered, clayey shale. Depth to shale ranges from 84-120". Small grains.

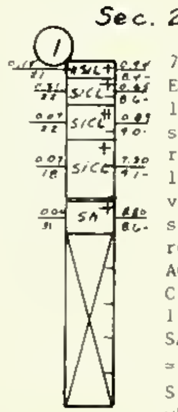

100' S., 1400' E. of W¼. 6-15% complex ridge-shallow soil over shale. Depth to olive covered shale ranges from 8-24" in unit. Ap-0-6", AC-6-8", C1ca-8-14", C2-14-20", 20"+ -shale. 14-20" zone: Gyp. Req. = -8.3; Lab texture-SiCL. Small grains.

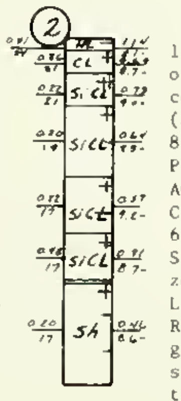

400'S. and 2250'E. of W¼. Refer to Point Site #11 for profile description and laboratory data (Appendix).

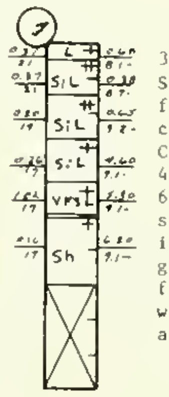
Sec. 22, T. 15 N., R. 53 E.

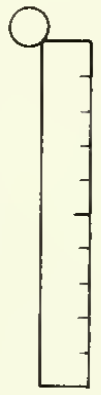

1000' S., 500' W of NE Corner. 0-2% complex; old alluvial terrace. Depth to sand & gravel varies in unit from 24-48". Scattered gravel/cobble on surface. Ap-0-6", B2-6-8", B3ca-8-13", C1ca-13-36", IIC-36"+. Small grains.

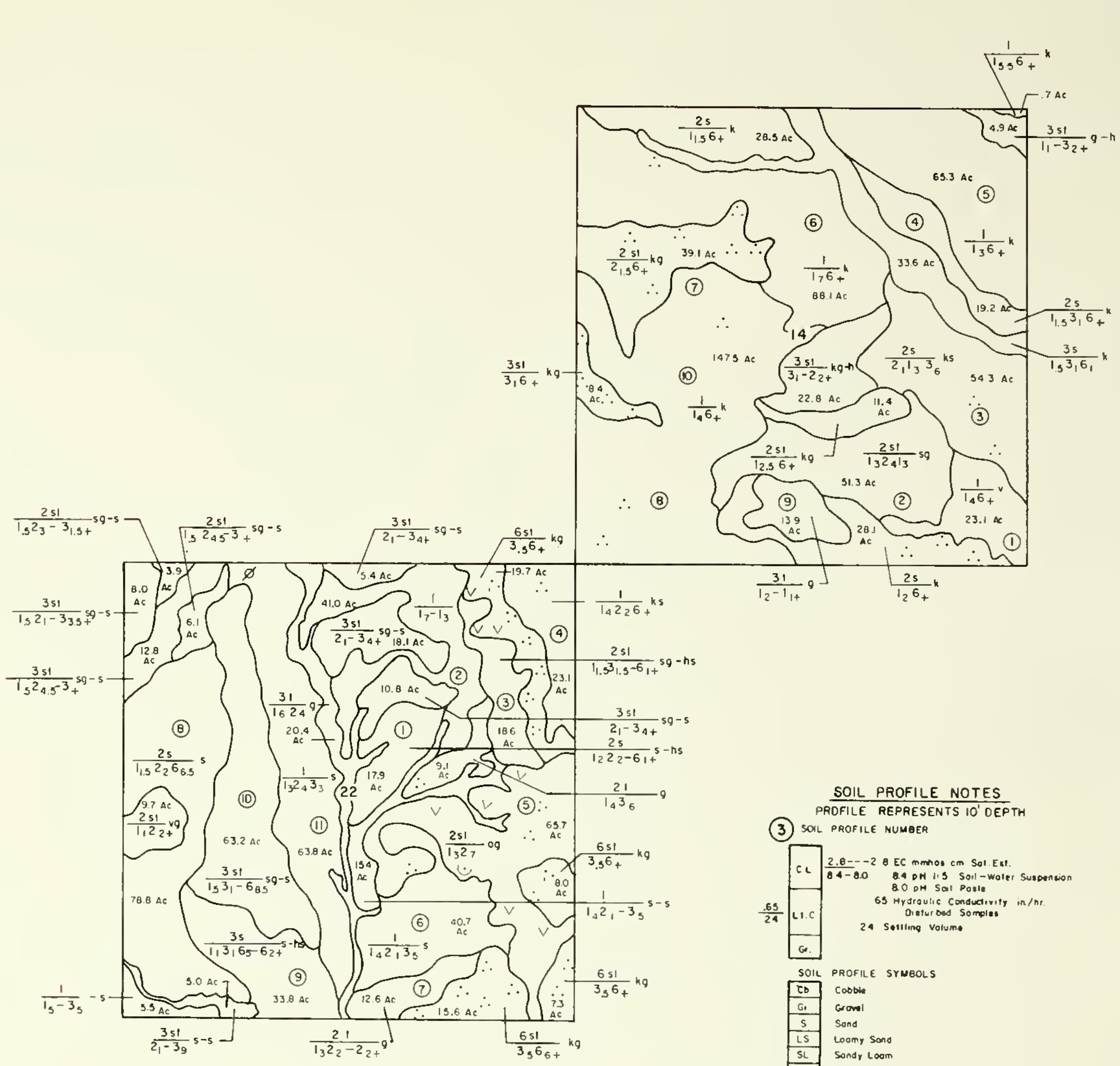

1600' S., 125' E. of N¼. 0-4% complex old alluvium. Surface has 5-10% gravel/cobble - localized highs in unit have 30-40% surface gravel/cobble. Ap-0-6", B2-6-8", B3ca-8-13", C1ca-13-26", C2-26"+ 0-8" zone: Gyp. Req. = +3.44; Lab texture - L. Small grains.


700' N., 2000' W. of E¼. 4-8% complex, uplands. Unit includes severely eroded ridges (highs) & local alluvial/colluvial fill. 48"-clayey shale-place below root zone. A1-0-2", AC-2-5", C1-5-14", C2ca-14-26", C3-26-48 IIC-48"+. 26-48" zone: SAR = 1.73; Gyp. Req. = +1.8; Lab texture-SiL. Range-Western wheatgrass, Needleandthread.


1600' S., 1600' N. of NE Corner. 4-8% complex, fill area (alluvial/colluvial) 84" + silty shale. Profile- A1-0-2", AC-2-4", C1-4-12", C2ca-12-24", C3-24-66", C4-66-84", 84"+ Silty shale. 24-48" zone: SAR = 2.5; Lab texture - SiL. Range-Western wheatgrass, Little bluestem, Needleandthread.


350' N., 850' E. of S¼. 6-12% complex, footslope (alluvial/colluvial). A1-0-1", C1ca-1-32", C2-32-45", C3-45-60", IIC-60-84"+ weathered silty shale. Highs in unit have 10-20% gravel/cobble (surface). Range-Western wheatgrass, Needleandthread.





1000 0 1000 2000 3000

SCALE OF FEET

LAND CLASSIFICATION SYMBOLS

LAND CLASS — 3st — Plant media deficiency
Topographic deficiency
SURFACE LAYER 2,3,6 - 3,3 sg-o — Informative symbols
Quality
Depth (Ft)
SECOND LAYER
Quality
Depth (Ft)
10.0 — No of Acres
GEOLOGIC MATERIAL
Quality
Depth (Ft)
Divides soil material and geologic material

SOIL PROFILE NOTES

PROFILE REPRESENTS 10' DEPTH

③ SOIL PROFILE NUMBER

2.8---2 8 EC mmhos cm Sat Ext.
8.4-8.0 8.4 pH 1:5 Soil-Water Suspension
8.0 pH Sat Paste
.65 Hydraulic Conductivity in/hr. Disturbed Samples
24 Setting Volume

SOIL PROFILE SYMBOLS

Cb	Cobble
Gr	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
SiL	Silt Loam
Si	Silt
SCL	Sandy Clay Loam
CL	Clay Loam
SiCL	Silty Clay Loam
SC	Sandy Clay
SiC	Silty Clay
C	Clay
Sh	Shale
Ss	Sandstone
F	Fine
Lt	Light
M	Medium
H	Heavy

CONVENTIONAL AND SPECIAL MAP SYMBOLS

LAND FEATURES

◡	Blowout
✕	Clay spot
∴	Gravelly Cobbly spot
Ø	Gumbo, slick or scabby spot (sodic)
≡	Dumps and similar nonsoil areas
V	Rock outcrop (includes shale and sandstone)
V̇	Baked rock (scoria) outcrop
⸙	Slide or slip (tips point upslope)
⦀	Stony spot, very stony spot
#	Greasewood

WATER FEATURES

⩩	Marsh or swamp
o	Spring
♁	Well, artesian
-o-	Well, irrigation
✦	Wet spot

PITS

⚒	Gravel
⚒	Mine

DAMS

◁	Medium or small

INFORMATIVE SYMBOLS

PLANT MEDIA DEFICENCIES

o	Sodicity
s	Salinity
h	Clay (very fine texture)
v	Coarse (very sandy texture)
k	Gravel (soil profile)
q	Available moisture capacity
x	Cobbly, stony, flaggy or clinkers (soil profile)
b	Bedrock (hard or partially weathered)

TOPOGRAPHIC DEFICENCIES

g	Slope (including gradient and complexity)
r	Exposed bedrock (outcrops)

N

DAWSON COUNTY
SECTIONS 14 & 22 - T. 15 N., R. 53 E.

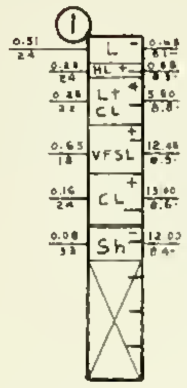
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
NORTHEAST MONTANA INVESTIGATIONS
SOUTHWEST GLENDIVE STUDY AREA - MONTANA

SEMI-DETAILED LAND CLASSIFICATION

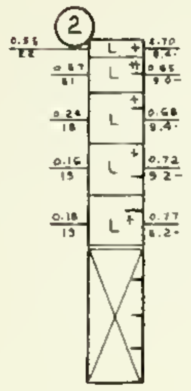
CLASSIFIED O WESTMAN FIELD APPROVAL
DRAWN L E ALLSOP TECHNICAL APPROVAL
CHECKED APPROVED

BILLINGS, MONTANA MARCH, 1983 1305-600-368

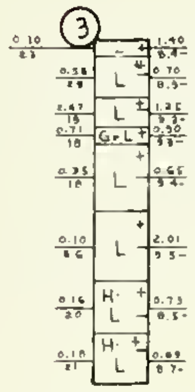
E. 1/2 SECTION 6



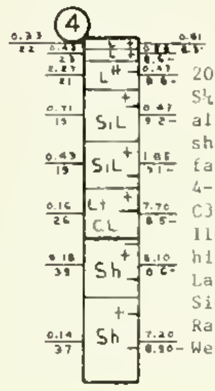
① 225'S., 1000' W. of NE Corner. 0-6% complex, fill area (alluvial/colluvial) at base of slope. Clayey shale at 66"+. Salt crystals visible at 48"+. Ap-0-6", AC-6-8", C1-8-14", C2ca-14-30", C3-30-48", C4-48-66", IIC-66"+, 48-66" zone: Lab texture - SiCL; Gyp. Req. = -1.2. Small grains.



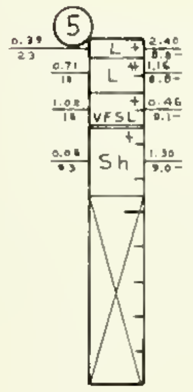
② 1000'S., 1350' W. of NE Corner. 8-15% complex, ridge sample. Unit includes small shale outcrops & severely eroded spots - depth to shale in those spots is 6-24". Unable to penetrate >72" hard bedrock. A1-0-4", AC-4-7", C1ca-7-18", C2-18-72", IIC-72"+. 36-54" zone: SAR = 0.58; Gyp. Req. = +3.0; Lab texture - SiL. Range-Needleandthread, Fringed sagewort.



③ 850' N., 1600' W. of E½. 0-6% complex, fill area (alluvial) adjacent to drainage Thin gravelly zone: 30-36". Ap-0-4", AC-4-5", C1ca -5-20". C2 -20-84", C3-84-120 60-84" zone: SAR = 7.66; Lab Texture - SiL. Small grains.



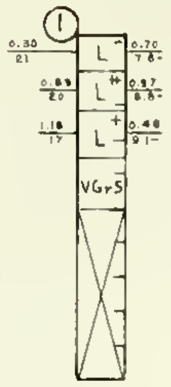
④ 2000' N., 250' E. of S½. 0-8% complex, alluvium over soft shale (dissected fans). A1-0-4", c1-4-9", C2ca-9-18", C3-18-52", C4-52-68", IIC-68-120"(shales highly weathered). Lab textures: 68-90" SiCL; 90-120" -SiC. Range-Needleandthread Western wheatgrass.



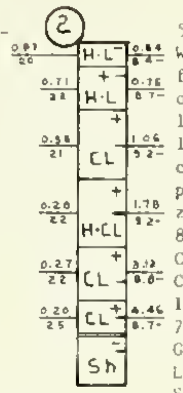
⑤ 1000' S., 1100' W. of E½. 6-25% complex ridge in semibadlands unit. Some eroded sideslopes to 35%. Olive-gray clayey shale-slow perma. A1-0-2", C1-2-6", C2ca-6-11", C3-11-18", C4-18-30", IIC-30"+. 30-54"+ zone: SAR = +0.17; Lab texture SiL. Range-Needleandthread, Bluebunch wheatgrass, Wildrose, forbs.

⑥ 625' S., 1200' W. of E½. Refer to Point Site #6 Profile Description and laboratory data. (Appendix).

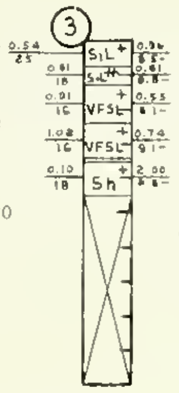
SECTION 8



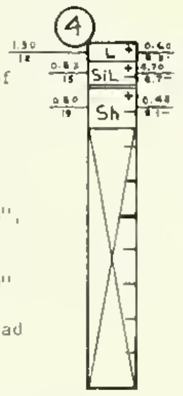
① 200' S., 1100' W. of N½. 0-8% complex, upland alluvial bench remnant. Depth to sand & gravel ranges in unit from 24-50". Ap-0-5", B2-5-12", B3-12-16", C1ca-16-26", C2-26-42", IIC-42"+. Small grains.



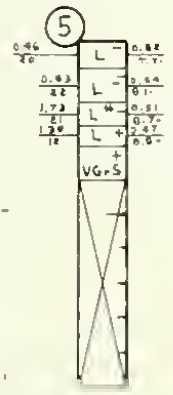
② 550' N., 350' E. of W½. 0-4% complex, fill area (alluvium) over shale/lignite. 102" + lignite(3" layer) underlain by carbonaceous shale-place below root zone. Ap-0-8", B2-8-14", B3-14-24", C1-24-48", C2-48-72", C3-72-90", C4-90-102" IIC-102-120"+. 48-72" zone: SAR = 2.88; Gyp. Req. = 3.82; Lab texture - SCL. Small grains.



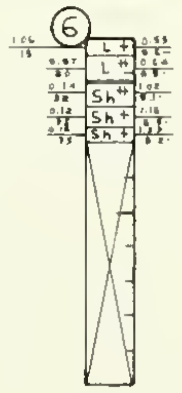
③ 1000' N., 625' E. of SW Corner. 8-15% complex, sideslope, local alluvium over silty shale. Ap-0-5", B2-5-8", B3ca-8-15", C1-15-28", C2-28-40", IIC-40+. Depth to weathered shale ranges in unit from 24-48". 15-26" zone: SAR = 0.07; Gyp. Req. = 2.42; Lab texture- Si. Small grains.



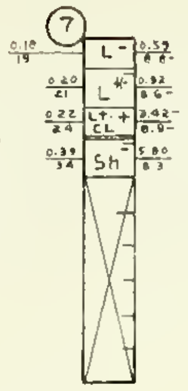
④ 1125'N., 925' W. of S½. 8-15% complex, ridge-line-residual soil over soft, silty shale. Ap-0-6", C1-6-14", C2-14-30+ (shale). Small grains Depth to weathered shale ranges in unit from 8-18". Slope to intermittent drainage is 20-25%.



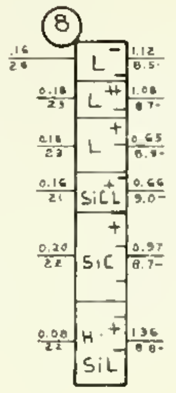
⑤ 1050' N., 1650' W. of E½. 0-8% complex. fill area-old alluvium washed from ridge to north. Ap-0-8", B2-8-14", B3-14-20", C1ca-20-28", C2-28-36", IIC-36-48"+. Depth to VGrS ranges from 24-48" in unit. Small grains.



⑥ 600' S., 600' W. of E½. 2-12% complex, ridge-line-shallow residual soil over interbedded shale and weathered fine sandstone. Where fine sandstone is encountered use for subsurface material-too erosive for surface use. Ap-0-6", C1-6-14", C2-14-24", C3-24-30", C4-30-36"+. 14-24" zone: SAR = 0.52; Gyp. Req. = +2.51; Small grains.Lab texture - SiCL.



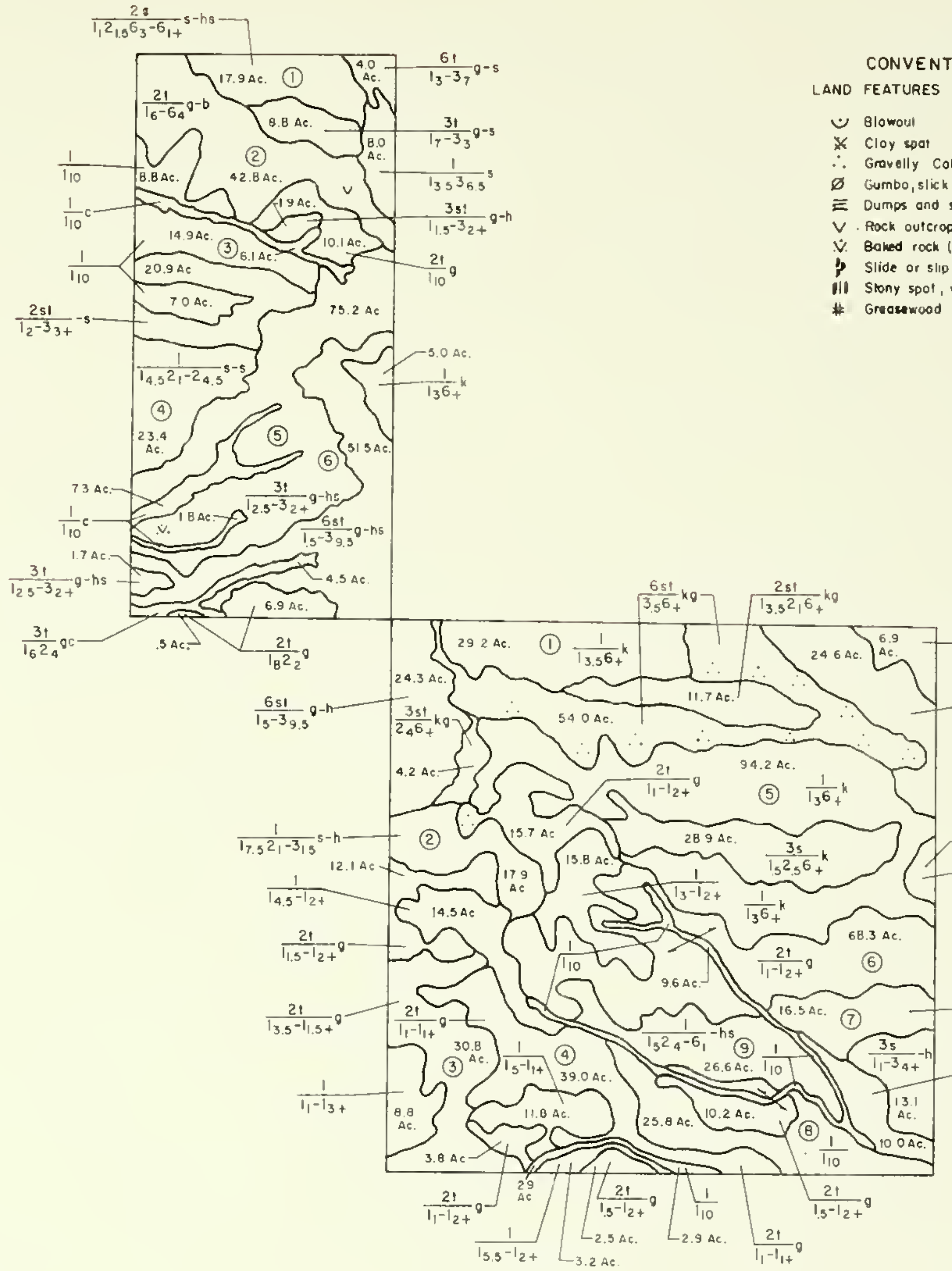
⑦ 1500' N., 800' W. of SE Corner. 0-6% complex, lower sideslope - slope wash (alluvium) over soft shale. Ap-0-8", weak B2-8-10", B3ca-10-17", C1ca-17-34", IIC-34-48"+. Depth to shale ranges in unit from 28-44". Small grains.



⑧ 400' N., 1200' W. of SE Corner. 0-4% complex, alluvial fill area. Ap-0-7", B2-7-14", B3ca-14-27", C1-27-46", C2-46-60", C3-60-90", C4-90-120". 60-90" zone: SAR = 0.60; Gyp. Req. = +2.69; Lab texture - C. Small grains.

⑨ 1200'N., 800' E. of S½.

Refer to Point Site #9 for profile description and laboratory data. (Appendix).



CONVENTIONAL AND SPECIAL MAP SYMBOLS

LAND FEATURES

◡	Blowout
✕	Clay spot
∴	Gravelly Cobbly spot
Ø	Gumbo, slick or scabby spot (sodic)
☰	Dumps and similar nonsoil areas
V	Rock outcrop (includes shale and sandstone)
V̇	Baked rock (scoria) outcrop
ϸ	Slide or slip (tips point upslope)
∥	Stony spot, very stony spot
✱	Greasewood

WATER FEATURES

⩛	Marsh or swamp
o	Spring
♁	Well, artesian
-o-	Well, irrigation
✦	Wet spot

PITS

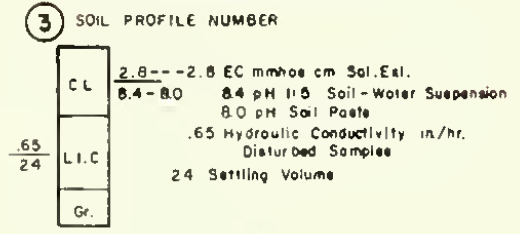
⚒	Gravel
⚒	Mine

DAMS

◁	Medium or small

SOIL PROFILE NOTES

PROFILE REPRESENTS 10' DEPTH

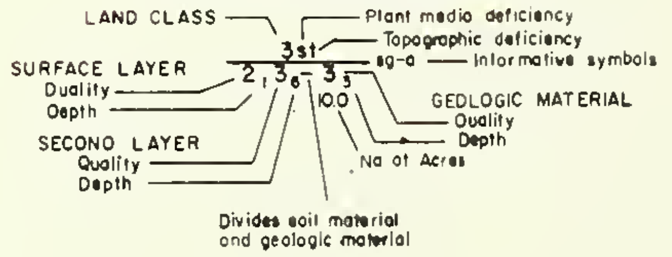


③ SOIL PROFILE NUMBER
CL
L.I.C
Gr.
.65
24
2.8---2.8 EC mmhos cm Sol.Ext.
8.4-8.0 8.4 pH 1:5 Soil-Water Suspension
8.0 pH Soil Paste
.65 Hydraulic Conductivity in./hr. Disturbed Samples
24 Settling Volume

SOIL PROFILE SYMBOLS

Cb	Cobble
Gr	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
SiL	Silt Loam
Si	Silt
SCL	Sandy Clay Loam
CL	Clay Loam
SiCL	Silty Clay Loam
SC	Sandy Clay
SiC	Silty Clay
C	Clay
Sh	Shale
Ss	Sandstone
F	Fine
Lt	Light
M	Medium
H	Heavy

LAND CLASSIFICATION SYMBOLS



INFORMATIVE SYMBOLS

PLANT MEDIA DEFICENCIES

a	Sodicity
s	Salinity
h	Clay (very fine texture)
v	Coarse (very sandy texture)
k	Gravel (soil profile)
q	Available moisture capacity
x	Cobbly, stony, floggy or clinkers (soil profile)
b	Bedrock (hard or partially weathered)

TOPOGRAPHIC DEFICENCIES

g	Slope (including gradient and complexity)
r	Exposed bedrock (outcrops)
c	Cover (trees)

1000 0 1000 2000 3000

SCALE OF FEET

DAWSON COUNTY

E 1/2 - SECTION 6, SECTION 8 - T. 20 N., R. 53 E.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

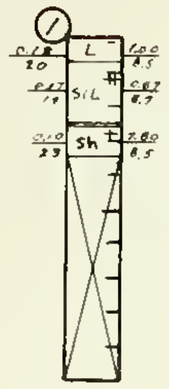
RESOURCE & POTENTIAL RECLAMATION EVALUATION

NORTHEAST MONTANA INVESTIGATIONS
UPPER THIRTEENMILE CREEK STUDY AREA – MONTANA

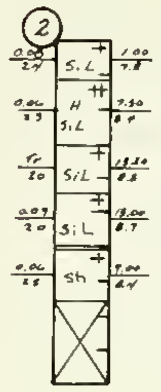
SEMI-DETAILED LAND CLASSIFICATION

CLASSIFIED G. WESTMAN   FIELD APPROVAL ____________
DRAWN R. GILSON   TECHNICAL APPROVAL ____________
CHECKED ____________   APPROVED ____________

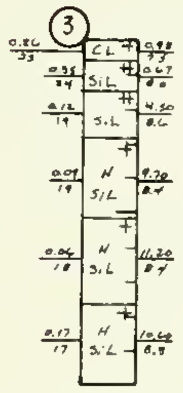
BILLINGS, MONTANA   MARCH, 1983   1305-600-369



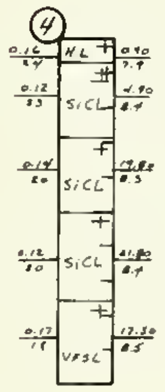
700' N., 1200' E. of SW Corner. 8-30% complex dissected fans - alluvium over soft shale. A1-0-2", C1-2-7", C2ca-7-30", 30+ - shale, highly weathered. Range - Western wheatgrass, Needleandthread, Fringed sagewort.



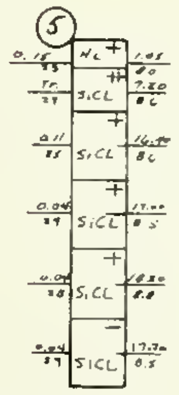
775' N., 975'E. of W½. 6-15% complex-some slopes adjacent to shale outcrops steeper. Dissected alluvial fans. Depth to shale varies from 48" near outcrops to 120" in small drainages. A1-0-2", B2-2-14", B3ca-14-21", C1ca-21-36", C2-36-72",>72" - shale. All samples SiL in lab; 36-54" zone: SAR = 2.3: Gyp. Req. = -0.96.



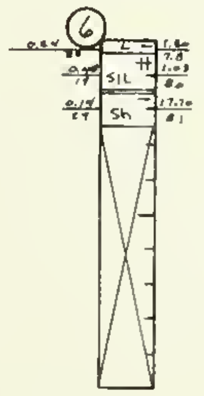
700' N., 2150' E. of W½. 0-8% complex, dissected alluvial fans. A1-0-3", B2-3-7", B3ca-7-16", C1ca-16-34", C2-34-120+. Some spots in unit have a gravelly layer from 36-48" (ancient drainage channels). All samples SiL in lab. Range- Western wheatgrass, Fringed sagewort, scattered Silver sagebrush.



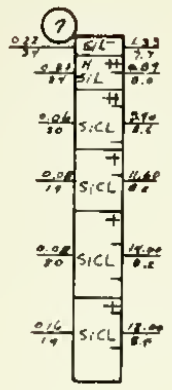
800' S. 550' W. of N½. 0-4% complex, alluvial fan/terrace feature. A1-0-2", B2-2-7", B3ca-7-14", C1ca-14-34", C2-34-90", C3-90-120"+. 60-90" zone: SAR = 6.1; Gyp. Req. = -4.4; Lab texture-SiL. Range - Western wheatgrass, Needleandthread, Fringed sagewort, scattered Silver sagebrush.



500' S., 1000' W. of NE Corner. 0-4% complex, alluvial fan/terrace feature. A1-0-2", B2-2-8", B3ca-8-17", C1ca-17-24". C2-24-120"+. 24-48" zone: SAR = 14.4; Gyp. Req. = +0.43. Range- Western wheatgrass, Fringed sagewort, Needleandthread.



475' N., and 575' W. f E½. 6-25% complex ridge shallow, residual soil over olive-colored shale (textured to silty clay). A1-0-1" C1-1-4", C2ca-4-16", C3-16"+. Range- Western wheatgrass, Little bluestem, Fringed sagewort.

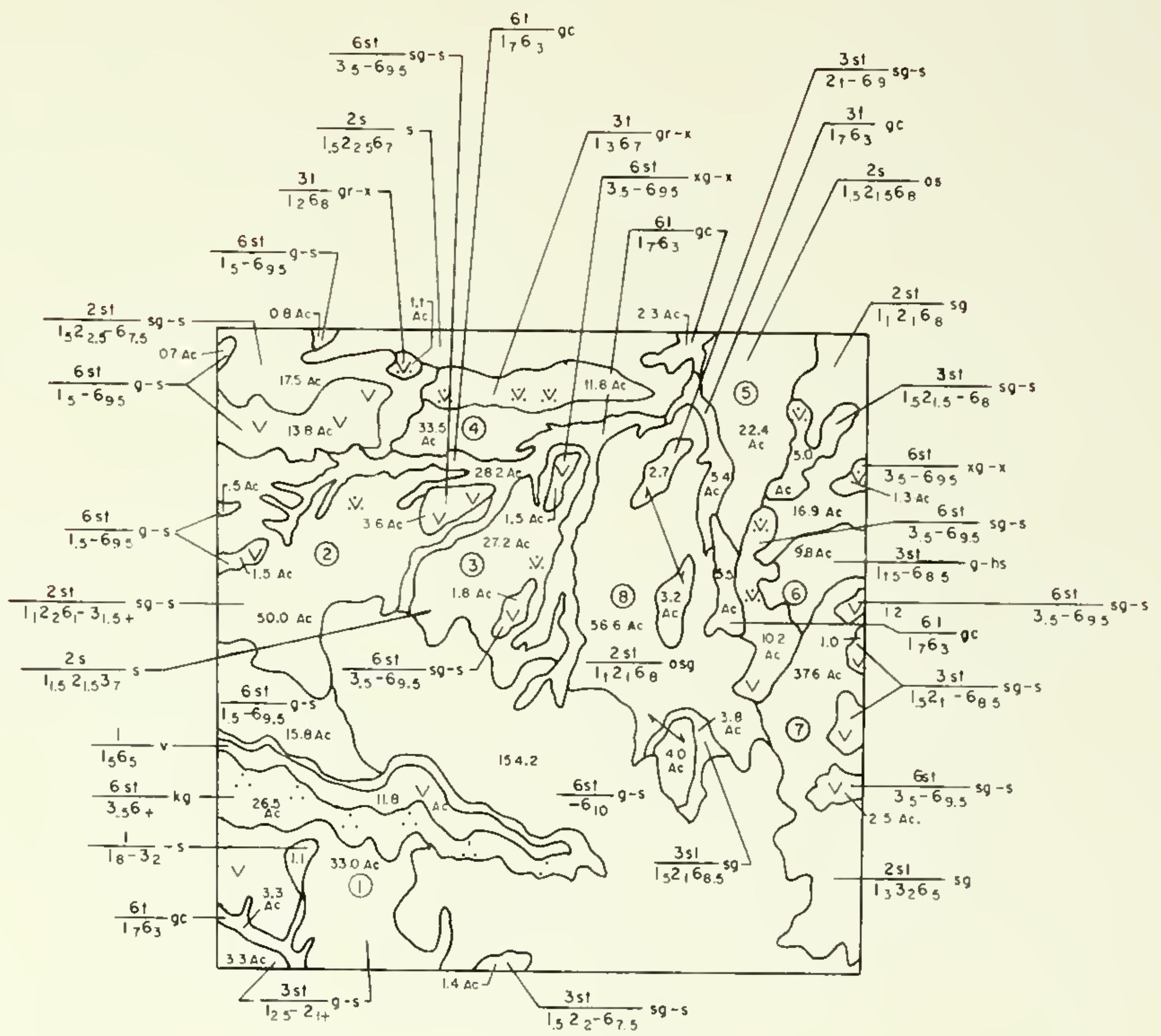


650' S., 525' W. of E½. 6-15% complex, unit includes dissected alluvial fans and small intermittent drainages. Some slopes adjacent to localized outcrops are steeper. A1-0-2", B2-2-7", B3ca-7-16", C1ca-16-38", C2-38-120"+. Range - Western wheatgrass, Buffalograss, Fringed sagewort, scattered Silver sagebrush.

⑧

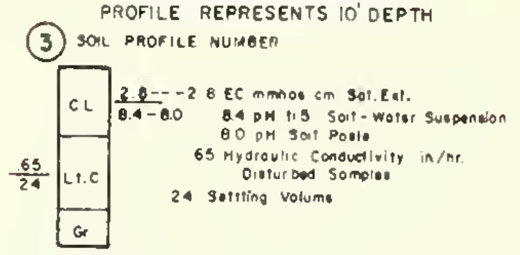
475' N., 2050' W. of E½.

Refer to Point Site #8 for profile description and laboratory data. (Appendix)


$\frac{6st}{3_5-6_{9.5}}$ sg-s
$\frac{6t}{1_7 6_3}$ gc
$\frac{2s}{1_5 2_{2.5} 6_7}$ s
$\frac{3t}{1_3 6_7}$ gr-x
$\frac{6st}{3_5-6_{9.5}}$ xg-x
$\frac{3t}{1_2 6_8}$ gr-x
$\frac{6t}{1_7 6_3}$ gc
$\frac{3st}{2_1-6_9}$ sg-s
$\frac{3t}{1_7 6_3}$ gc
$\frac{2s}{1_5 2_1 5 6_8}$ os
$\frac{6st}{1_5-6_{9.5}}$ g-s
$\frac{2st}{1_5 2_{2.5}-6_{7.5}}$ sg-s
$\frac{6st}{1_5-6_{9.5}}$ g-s
$\frac{2st}{1_1 2_1 6_8}$ sg
$\frac{3st}{1_5 2_{1.5}-6_8}$ sg-s
$\frac{6st}{3_5-6_{9.5}}$ xg-x
$\frac{6st}{3_5-6_{9.5}}$ sg-s
$\frac{6st}{1_5-6_{9.5}}$ g-s
$\frac{3st}{1_{1.5}-6_{8.5}}$ g-hs
$\frac{2st}{1_1 2_2 6_1-3_{1.5+}}$ sg-s
$\frac{6st}{3_5-6_{9.5}}$ sg-s
$\frac{6t}{1_7 6_3}$ gc
$\frac{2s}{1_{1.5} 2_{1.5} 3_7}$ s
$\frac{6st}{3_5-6_{9.5}}$ sg-s
$\frac{2st}{1_1 2_1 6_8}$ osg
$\frac{3st}{1_5 2_1-6_{8.5}}$ sg-s
$\frac{6st}{1_5-6_{9.5}}$ g-s
$\frac{1}{1_5 6_5}$ v
$\frac{6st}{3_5 6_+}$ kg
$\frac{6st}{-6_{10}}$ g-s
$\frac{6st}{3_5-6_{9.5}}$ sg-s
$\frac{1}{1_8-3_2}$ -s
$\frac{3st}{1_5 2_1 6_{8.5}}$ sg
$\frac{2st}{1_3 3_2 6_5}$ sg
$\frac{6t}{1_7 6_3}$ gc
$\frac{3st}{1_2 5-2_{1+}}$ g-s
$\frac{3st}{1_5 2_2-6_{7.5}}$ sg-s
0.8 Ac
1.1 Ac
2.3 Ac
0.7 Ac
17.5 Ac
13.8 Ac
33.5 Ac
④
11.8 Ac
⑤
22.4 Ac
5.0
.5 Ac
28.2 Ac
3.6 Ac
1.5 Ac
2.7
5.4 Ac
Ac
16.9 Ac
1.3 Ac
②
27.2 Ac
③
9.8 Ac
1.5 Ac
1.8 Ac
⑧
3.2 Ac
5.5
⑥
50.0 Ac
56.6 Ac
Ac
1.2
10.2 Ac
1.0
37.6 Ac
15.8 Ac
3.8 Ac
⑦
154.2
4.0 Ac
26.5 Ac
11.8 Ac
2.5 Ac.
1.1
33.0 Ac
①
3.3 Ac
3.3 Ac
1.4 Ac

SOIL PROFILE NOTES

PROFILE REPRESENTS 10' DEPTH



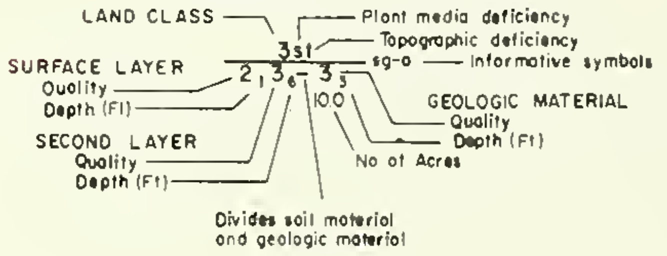
③ SOIL PROFILE NUMBER

2.8 - - -2.8 EC mmhos cm Sat. Ext.
8.4 - 8.0 8.4 pH 1:5 Soil-Water Suspension
8.0 pH Sat Paste
.65 Hydraulic Conductivity in/hr. Disturbed Samples
24 Settling Volume

SOIL PROFILE SYMBOLS

Cb	Cobble
Gr	Gravel
S	Sand
LS	Loamy Sand
SL	Sandy Loam
L	Loam
SiL	Silt Loam
Si	Silt
SCL	Sandy Clay Loam
CL	Clay Loam
SiCL	Silty Clay Loam
SC	Sandy Clay
SiC	Silty Clay
C	Clay
Sh	Shale
Ss	Sandstone
F	Fine
Lt	Light
M	Medium
H	Heavy

LAND CLASSIFICATION SYMBOLS



INFORMATIVE SYMBOLS

PLANT MEDIA DEFICENCIES

a	Sodicity
s	Salinity
h	Clay (very fine texture)
v	Coarse (very sandy texture)
k	Gravel (soil profile)
q	Available moisture capacity
x	Cobbly, stony, flaggy or clinkers (soil profile)
b	Bedrock (hard or partially weathered)

TOPOGRAPHIC DEFICENCIES

g	Slope (including gradient and complexity)
r	Exposed bedrock (outcrops)
c	Cover (trees)

CONVENTIONAL ANO SPECIAL MAP SYMBOLS

LAND FEATURES

◡	Blowout
✕	Clay spot
∴	Gravelly Cobbly spot
Ø	Gumbo, slick or scabby spot (sodic)
≡	Dumps and similar nonsoil areas
V	Rock outcrop (includes shale and sandstone)
V̇	Baked rock (scoria) outcrop
⚡	Slide or slip (tips point upslope)
ıłł	Stony spot, very stony spot
#	Greasewood

WATER FEATURES

⩸	Marsh or swamp
o	Spring
⊸	Well, artesian
-○-	Well, irrigation
↓	Wet spot

PITS

⚒	Gravel
⚒	Mine

DAMS

◁	Medium or small

1000 0 1000 2000 3000
SCALE OF FEET

DAWSON COUNTY
SECTION 4 - T. 20 N., R. 56 E.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

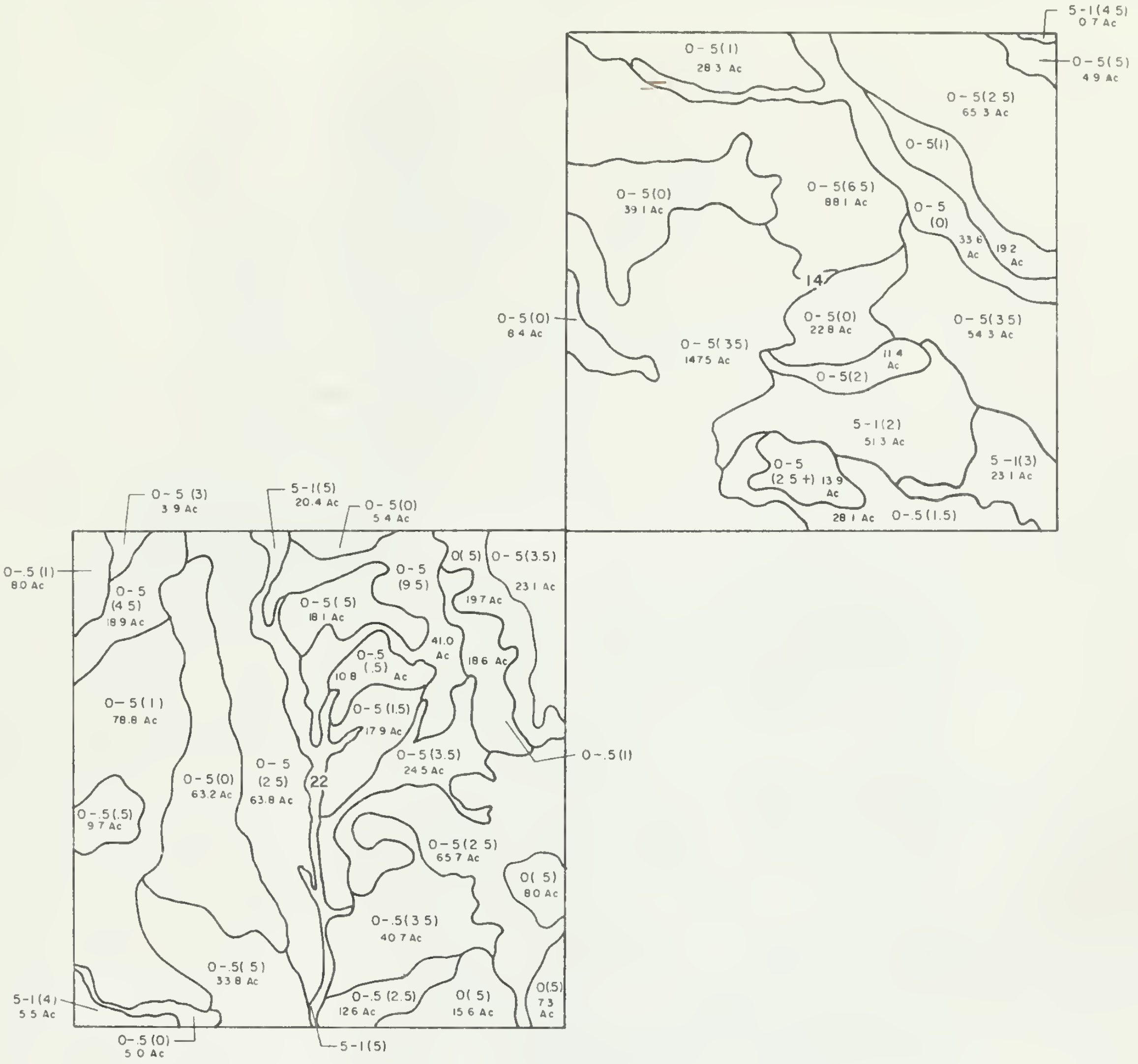
RESOURCE & POTENTIAL RECLAMATION EVALUATION

NORTHEAST MONTANA INVESTIGATIONS
WOODSON PRLA STUDY AREA

SEMI-DETAILED LAND CLASSIFICATION

CLASSIFIED G. WESTMAN FIELD APPROVAL ______
DRAWN L.E. ALLSOP TECHNICAL APPROVAL ______
CHECKED ______ APPROVED ______
BILLINGS, MONTANA MARCH, 1983 1305-600-370

PLATE 29



EXPLANATION

DEPTH (FT.) OF PREFERRED MATERIAL* — DEPTH (FT) OF ACCEPTABLE MATERIAL**

5-1 (1)

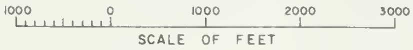
25 0 Ac - ACREAGE

NOTES.

*Preferred material refers to material that is highly desirable for surface placement in a reconstructed profile It is nonsaline, nonsodic, and permeable.

**Acceptable material refers to additional good quality material immediately below the preferred material. This material may contain slightly higher levels of soluble salts or exchangeable sodium than the preferred material In most cases, mixing of the preferred and acceptable materials should not appreciably change the overall quality of the topsoil.

DAWSON COUNTY
SECTIONS 14 & 22 - T 15 N., R 53 E.

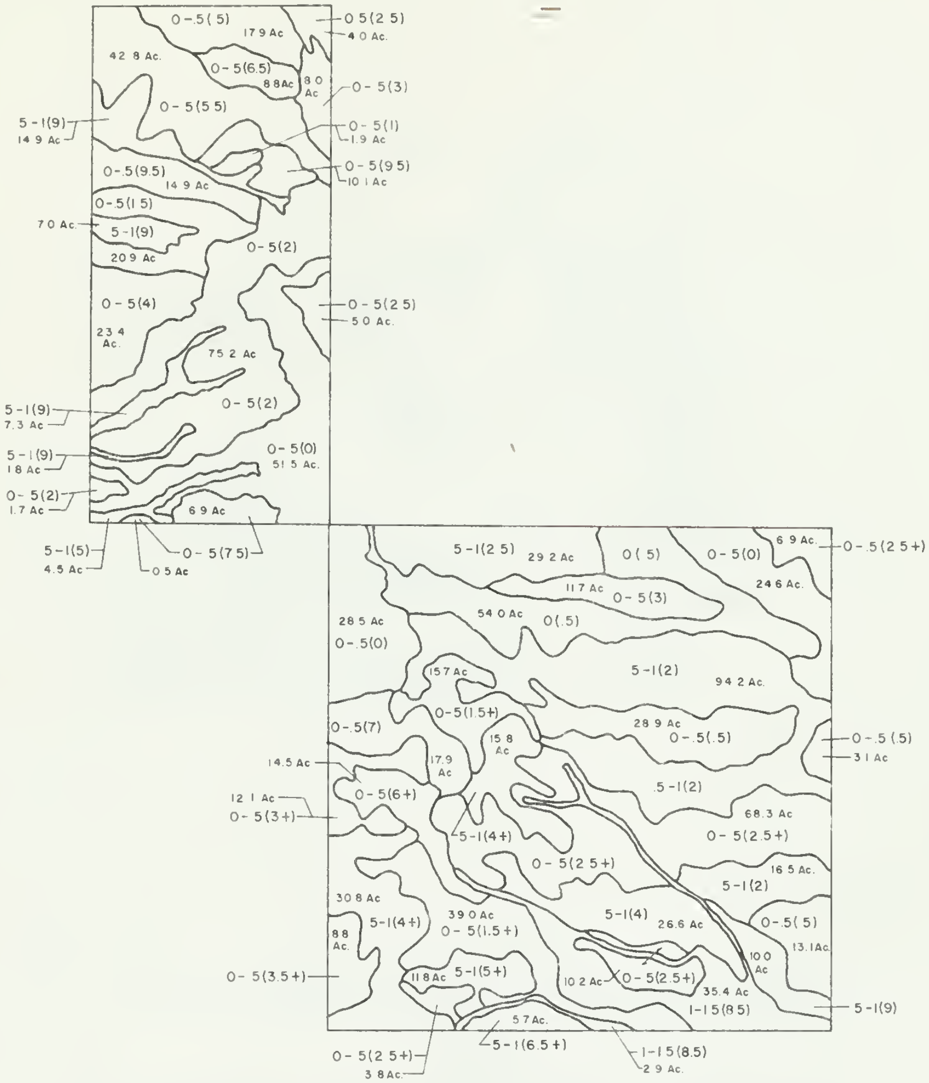


UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION

NORTHEAST MONTANA INVESTIGATIONS
SOUTHWEST GLENDIVE STUDY AREA - MONTANA

TOPSOILING MATERIAL

CLASSIFIED G. WESTMAN FIELD APPROVAL
DRAWN L. E. ALLSOP TECHNICAL APPROVAL
CHECKED APPROVED
BILLINGS, MONTANA MARCH, 1983 1305-600-371



EXPLANATION

DEPTH (FT.) OF PREFERRED MATERIAL* ┐ ┌ DEPTH (FT) OF ACCEPTABLE MATERIAL**

.5-1 (1)

25 0 Ac - ACREAGE

NOTES:

*Preferred material refers to material that is highly desirable for surface placement in a reconstructed profile. It is nonsaline, nonsodic, and permeable

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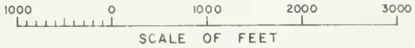
DAWSON COUNTY
E 1/2 - SECTION 6, SECTION 8 - T. 20 N., R. 53 E.



UNITED STATES
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RESOURCE & POTENTIAL RECLAMATION EVALUATION

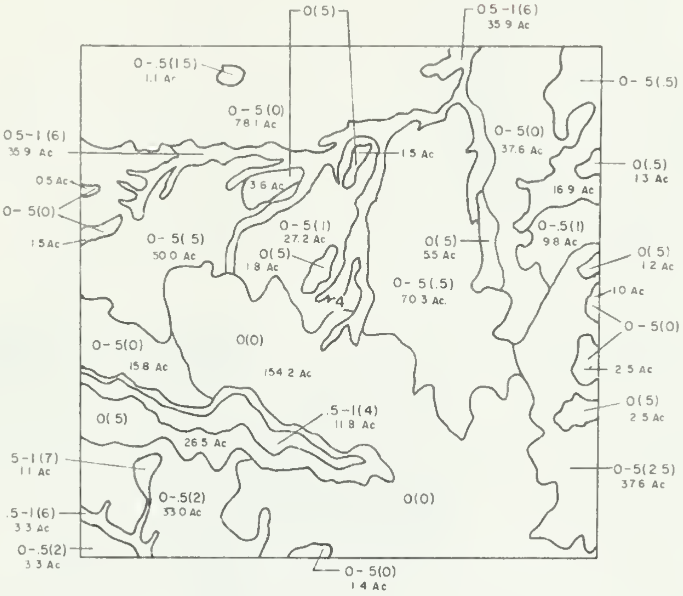
NORTHEAST MONTANA INVESTIGATIONS
UPPER THIRTEENMILE CREEK STUDY AREA - MONTANA

TOPSOILING MATERIAL

CLASSIFIED G. WESTMAN FIELD APPROVAL
DRAWN R. GILSON TECHNICAL APPROVAL
CHECKED APPROVED

BILLINGS, MONTANA MARCH, 1983 1305-600-372

PLATE 31



EXPLANATION

DEPTH (FT.) OF PREFERRED MATERIAL* — DEPTH (FT.) OF ACCEPTABLE MATERIAL**

5-1 (1)

25.0 Ac - ACREAGE

NOTES

*Preferred material refers to material that is highly desirable for surface placement in a reconstructed profile. It is nonsaline, nonsodic, and permeable.

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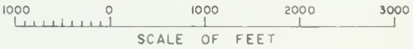


DAWSON COUNTY
SECTION 4 - T. 20 N., R. 56 E.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

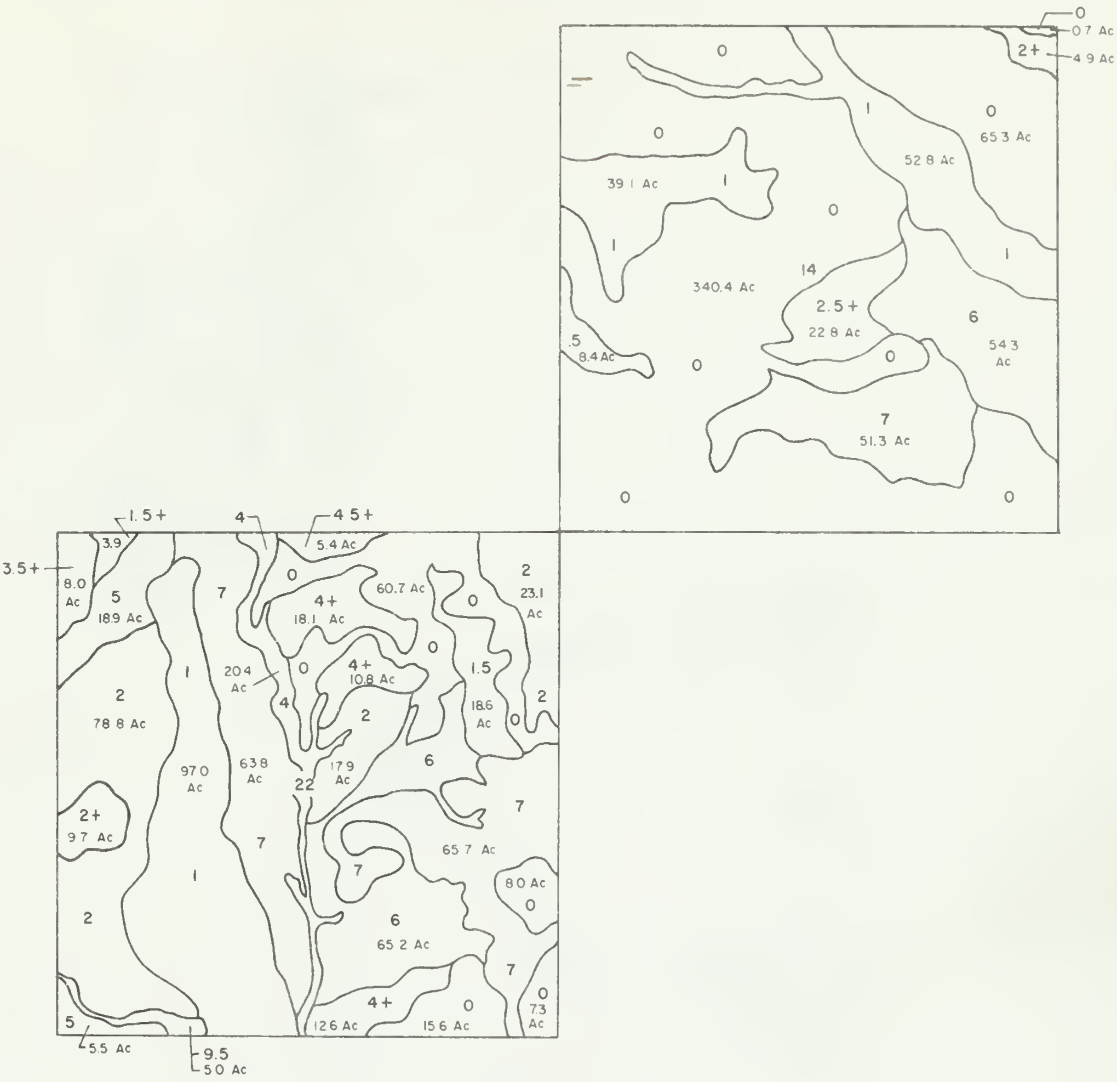
RESOURCE & POTENTIAL RECLAMATION EVALUATION

NORTHEAST MONTANA INVESTIGATIONS
WOODSON PRLA STUDY AREA - MONTANA

TOPSOILING MATERIAL

CLASSIFIED G. WESTMAN FIELD APPROVAL
DRAWN L. E. ALLSOP TECHNICAL APPROVAL
CHECKED APPROVED

BILLINGS, MONTANA MARCH, 1983 1305-600-373



EXPLANATION

QUANTITY OF USABLE MATERIAL

MATERIAL FOR PLACEMENT BELOW PRIMARY PLANT ROOT ZONE

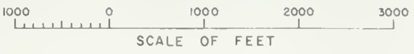
DEPTH IN FEET 2[1]

[1] ADDITIONAL MATERIAL IMMEDIATELY BELOW TOPSOILING MATERIAL

NOTE:

Usable material for subsurface placement, as used in this report, includes that portion of the overburden (soil mantle or bedrock) that should be placed below the primary plant root zone in reconstructed profiles This material may be slowly permeable or moderately saline/sodic, but is well suited for placement as indicated It is not suitable for use at or near the surface without addition of chemical amendments, leaching, etc

DAWSON COUNTY
SECTIONS 14 & 22 - T 15 N R 53 E



UNITED STATES
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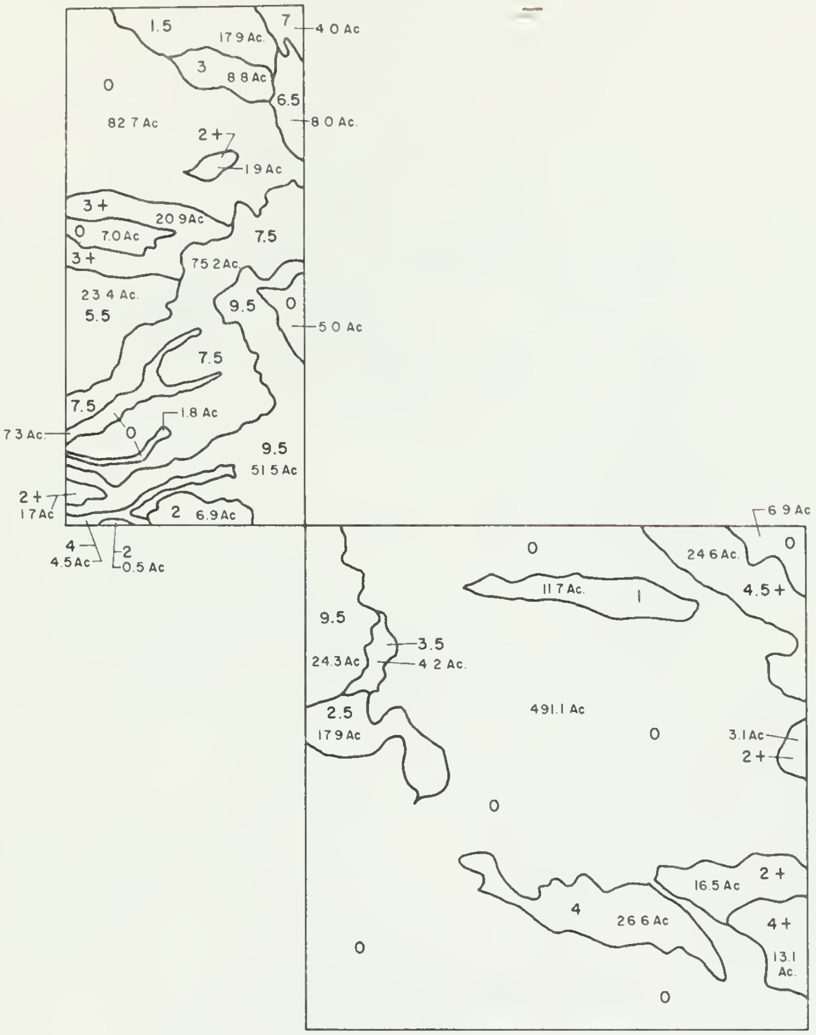
RESOURCE & POTENTIAL RECLAMATION EVALUATION

NORTHEAST MONTANA INVESTIGATIONS
SOUTHWEST GLENDIVE STUDY AREA - MONTANA

SUBSURFACE MATERIAL

CLASSIFIED G. WESTMAN FIELD APPROVAL
DRAWN L.E. ALLSOP TECHNICAL APPROVAL
CHECKED APPROVED

BILLINGS, MONTANA MARCH, 1983 1305-600-374



EXPLANATION

QUANTITY OF USABLE MATERIAL

MATERIAL FOR PLACEMENT BELOW PRIMARY PLANT ROOT ZONE

DEPTH IN FEET 2[1]

[1] ADDITIONAL MATERIAL IMMEDIATELY BELOW TOPSOILING MATERIAL

NOTE

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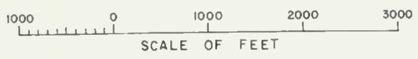
DAWSON COUNTY
E 1/2 - SECTION 6, SECTION 8 - T. 20 N., R. 53 E.



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

RESOURCE & POTENTIAL RECLAMATION EVALUATION

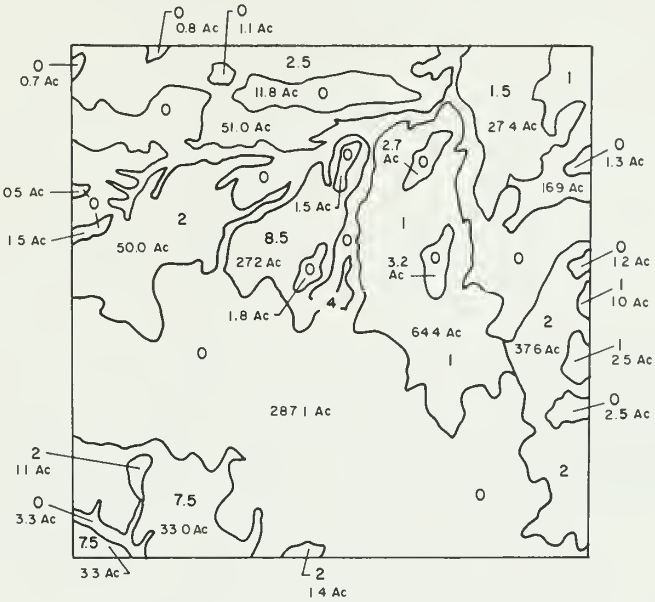
NORTHEAST MONTANA INVESTIGATIONS
UPPER THIRTEENMILE CREEK STUDY AREA – MONTANA

SUBSURFACE MATERIAL

CLASSIFIED G WESTMAN FIELD APPROVAL
DRAWN R GILSON TECHNICAL APPROVAL
CHECKED APPROVED

BILLINGS, MONTANA MARCH, 1983 1305-600-375

PLATE 34



EXPLANATION

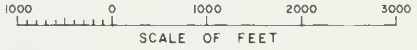
QUANTITY OF USABLE MATERIAL
MATERIAL FOR PLACEMENT BELOW PRIMARY PLANT ROOT ZONE

DEPTH IN FEET 2[1]

[1] ADDITIONAL MATERIAL IMMEDIATELY BELOW TOPSOILING MATERIAL

NOTE

Usable material for subsurface placement, as used in this report, includes that portion of the overburden (soil mantle or bedrock) that should be placed below the primary plant root zone in reconstructed profiles This material may be slowly permeable or moderately saline/sodic, but is well suited for placement as indicated It is not suitable for use at or near the surface without addition of chemical amendments, leaching, etc



DAWSON COUNTY
SECTION 4 - T. 20 N., R. 56 E.

N

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
RESOURCE & POTENTIAL RECLAMATION EVALUATION
NORTHEAST MONTANA INVESTIGATIONS
WOODSON PRLA STUDY AREA - MONTANA

SUBSURFACE MATERIAL

CLASSIFIED G. WESTMAN FIELD APPROVAL
DRAWN L. E. ALLSOP TECHNICAL APPROVAL
CHECKED APPROVED

BILLINGS, MONTANA MARCH, 1983 1305-600-376

Table 3

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION
POINT SITE LAND CHARACTERIZATION
(WITH DETERMINATIONS)

Study Area: Southwest Glendive, MT
Location. Sec. 14 Twp. 15N. Range 53E.
500' S. & 1300' E. of W¼ Corner
Climate: Semi-arid
Land Use: Cropland
Point Site Number: 10

Relief: Simple, concave
Elevation:
Slope: Aspect: 2%, E-NE
Vegetation: Small grains
Erosion: slight

Stoniness:
Drainage: Well drained
Ground Water:
Land Form: High terrace

Parent Material: Old Alluvium
Soil Series: Shambo (like)
Soil Classification: Coarse - loamy, mixed, Typic Haploboroll
Profile Description By: W. Volk Date: 7/81
Correlated By: W. Volk Date: 7/81

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION	
V-60	0.0-6.0	Ap	Dark brown (10YR 4/3) loam; very dark grayish brown (10YR 3/2) moist; moderate fine granular structure; soft; very friable; slightly sticky; slightly plastic; noneffervescent; abrupt smooth boundary.
V-61	6.0-13.0	B2	Yellowish brown (10YR 5/4) silt loam; dark brown (10YR 4/3) moist; moderate coarse prismatic structure breaks to moderate medium angular blocky; slightly hard; very friable; slightly sticky; slightly plastic; noneffervescent; clear smooth boundary.
V-62	13.0-26.0	B3k	Pale brown (10YR 6/3) silt loam; yellowish brown (10YR 5/4) moist; moderate coarse prismatic structure parts to moderate medium angular blocky; slightly hard; very friable; slightly sticky; slightly plastic; violent effervescence; clear wavy boundary.
V-63	26.0-33.0	C1k	Light yellowish brown (10YR 6/4) silt loam; yellowish brown (10YR 5/4) moist; weak coarse prismatic structure breaks to weak medium angular blocky; slightly hard; friable; slightly sticky; slightly plastic, strong effervescence; clear wavy boundary.
V-64	33.0-56.0	C2	Pale brown (10YR 6/3) silt loam; yellowish brown (10YR 5/4) moist; massive; slightly hard; friable; slightly sticky; slightly plastic; slight effervescence; abrupt wavy boundary.
	56.0 +	IIC2	Sand and gravel deposits - not sampled.
			Greenhouse Samples G-176 - 0-13" G-177 - 13-33" G-178 - 33-56"

LABORATORY DESCRIPTION

DETERMINATION		DATA				
LABORATORY NUMBER		V-60	V-61	V-62	V-63	V-64
DEPTH	(in)	0-6	6-13	13-26	26-33	33-56
PARTICLE SIZE ANALYSIS	(percent)					
Very Coarse Sand	(2.0-1.0 mm)					
Coarse Sand	(1.0-0.5 mm)					
Medium Sand	(0.5-0.25 mm)					
Fine Sand	(0.25-0.10 mm)					
Very Fine Sand	(0.10-0.05 mm)					
Total Sand	(2.0-0.05 mm)	29.2	31.9	20.5	3.8	10.6
Silt	(0.05-0.002 mm)	59.8	50.6	62.2	80.3	70.8
Clay	(< 0.002 mm)	11.0	17.5	17.3	15.9	18.3
TEXTURAL CLASS (LAB.)		SiL	SiL	SiL	Si	SiL
BULK DENSITY	(g/cm^3)					
HYDRAULIC CONDUCTIVITY	(in/hr)					
6th hr		1.42	2.91	1.34	1.02	1.50
24th hr		1.81	2.83	1.22	0.98	1.73
SETTLING VOLUME	(ml)	19	19	21	19	20
MOISTURE RETENTION	(percent)					
1/10 bar						
1/3 bar		16.8	17.4	20.7	19.8	20.9
15 bar		7.2	8.9	9.7	8.2	8.7
SOIL REACTION-pH						
Paste		6.4	7.1	7.9	8.4	8.5
1:5 H_2O		7.2	7.7	8.2	8.9	9.1
1:2 0.01 M $CaCl_2$						
ORGANIC CARBON	(percent)	1.5	1.1	1.0	0.4	0.2
AVAILABLE PHOSPHORUS	(ppm)					
$CaCO_3$ EQUIVALENT	(percent)					
GYPSUM REQUIREMENT	(me/100g)					
SATURATION EXTRACT						
Saturation Percentage		62.6	41.5	44.5	38.2	34.2
EC_e @ 25°C	(mmhas/cm)	0.90	0.50	0.40	0.54	0.90
Ca^{++}	(me/l)	4.6	3.3	2.6	1.2	0.5
Mg^{++}	(me/l)	2.3	1.3	1.0	2.8	3.0
Na^{+}	(me/l)	0.1	0.1	0.1	1.0	5.1
K^{+}	(me/l)	0.6	0.2	0.1	0.1	0.1
CO_3^-	(me/l)	0.0	0.0	0.0	0.0	0.0
HCO_3^-	(me/l)	1.4	4.0	2.5	2.6	3.2
Cl^-	(me/l)	0.0	0.0	0.0	0.0	0.1
SO_4^-	(me/l)	0.5	0.5	0.4	0.8	4.4
NO_3^-	(me/l)	5.2	0.5	0.8	1.5	0.6
SAR	(me/l)	0.1	0.1	0.1	0.7	3.9
Na	(me/100g)	0.0	0.0	0.0	0.0	0.2
Ca+Mg	(me/100g)					
1:5 EXTRACT						
EC_5 @ 25°C	(mmhas/cm)	0.11	0.11	0.13	0.16	0.24
Ca+Mg	(me/l)	0.7	0.8	1.2	1.2	1.1
EXCHANGEABLE SODIUM	(percent)	0.0	0.0	0.0	1.1	4.0
ACIDITY						
IN KCl exchange acidity						
Total	(me/100g)					
Al^{+++}	(me/100g)					
CATION EXCHANGE CAPACITY	(me/100g)	15.3	18.5	16.7	14.1	14.3
NaOAc@pH 8.2						
BORON	(mg/l)					

7-2006A (1-76)
Bureau of Reclamation

Table 4
Sheet 1 of 2

U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Southwest Glendive, MT
Location. Sec. 22 Twp. 15N Range
400' S. & 2250' E. of W½ Corner
Climate: Semi-arid
Land Use: Cropland
Point Site Number: 11

Relief: Simple, concave
Elevation: 2600 feet
Slope: Aspect: 3%, S-SE
Vegetation: Small grains
Erosion: Moderate

Stoniness: None
Drainage: Well drained
Ground Water:
Land Form: Lower sideslope

Parent Material: Alluvium
Soil Series: Farnuf (like)
Soil Classification: Fine - silty, mixed, Typic Haploboroll
Profile Description By: W. Volk Date: 7/81
Correlated By: W. Volk Date: 7/81

LAB AND FIELD NO.	DEPTH (Inches)		PROFILE DESCRIPTION
V-55	0.0-6.0	Ap	Brown (10YR 5/3) loam; very dark grayish brown (10YR 3/2) moist; moderate fine granular structure; soft; very friable; slightly sticky; slightly plastic; noneffervescent; abrupt smooth boundsry.
V-56	6.0-11.0	B2	Brown (10YR 5/3) heavy loam; dark brown (10YR 4/3) moist; moderate medium prismatic structure; slightly hard; very friable; slightly sticky; slightly plastic; slight effervescence; clear wavy boundary.
V-57	11.0-17.0	B3k	Pale brown (10YR 6/3) silt loam; brown (10YR 5/3) moist; weak medium prismatic structure; hard; friable; slightly sticky; slightly plastic; strong effervescence; clear wavy boundary.
V-58	17.0-38.0	C1k	Pale brown (10YR 6/3) silt loam; yellowish brown (10YR 5/4) moist; weak coarse angular blocky structure; hard; friable; slightly sticky; slightly plastic; violent effervescence; gradual diffuse boundary.
G-173	38.0-60.0	C2	Light yellowish brown (10YR 6/4) silt loam; yellowish brown (10YR 5/4) moist; massive; hard; friable; slightly sticky; slightly plastic; strong effervescence.

LABORATORY DESCRIPTION

DETERMINATION		DATA				
LABORATORY NUMBER		V-55	V-56	V-57	V-58	G-173
DEPTH	(in)	0-6	6-11	11-17	17-38	38-60
PARTICLE SIZE ANALYSIS	(percent)					
Very Coarse Sand	(2.0-1.0 mm)					
Coarse Sand	(1.0-0.5 mm)					
Medium Sand	(0.5-0.25 mm)					
Fine Sand	(0.25-0.10 mm)					
Very Fine Sand	(0.10-0.05 mm)					
Total Sand	(2.0-0.05 mm)	14.9	15.1	13.1	10.7	15.1
Silt	(0.05-0.002 mm)	67.0	60.5	57.0	57.5	59.5
Clay	(<0.002 mm)	18.1	24.4	29.9	31.8	25.4
TEXTURAL CLASS (LAB.)		SiL	SiL	SiCL	SiCL	SiL
BULK DENSITY	(g/cm^3)					
HYDRAULIC CONDUCTIVITY	(in/hr)					
6th hr		1.50	0.31	0.87	1.10	0.43
24th hr		1.67	0.22	0.87	1.10	0.43
SETTLING VOLUME	(ml)	20	20	21	22	22
MOISTURE RETENTION	(percent)					
1/10 bar						
1/3 bar		21.3	23.2	20.4	23.6	23.7
15 bar		9.9	9.6	9.4	10.5	8.4
SOIL REACTION-pH						
Paste		7.9	7.9	8.3	8.4	8.0
1:5 H_2O		8.2	8.3	8.7	8.8	8.3
1:2 0.01 M $CaCl_2$						
ORGANIC CARBON	(percent)	1.5	1.1	0.5	0.3	0.2
AVAILABLE PHOSPHORUS	(ppm)					
$CaCO_3$ EQUIVALENT	(percent)					
GYPSUM REQUIREMENT	(me/100g)					
SATURATION EXTRACT						
Saturation Percentage		39.6	37.6	38.6	46.2	41.9
EC_e @ 25°C	(mmhos/cm)	0.80	0.59	0.35	1.05	5.0
Ca^{++}	(me/l)	4.6	3.4	1.6	3.2	21.7
Mg^{++}	(me/l)	1.6	1.5	1.8	6.4	24.7
Na^+	(me/l)	0.4	0.5	0.4	1.1	22.7
K^+	(me/l)	0.5	0.1	0.0	0.0	0.2
CO_3^-	(me/l)	0.0	0.0	0.0	0.0	0.0
HCO_3^-	(me/l)	2.3	2.2	1.9	1.1	0.9
Cl^-	(me/l)	0.0	1.3	0.0	0.0	0.0
SO_4^-	(me/l)	0.9	1.6	1.4	9.2	68.0
NO_3^-	(me/l)	3.8	0.6	0.3	0.1	0.0
SAR	(me/l)	0.2	0.3	0.3	0.5	4.7
Na	(me/100g)	0.0	0.0	0.0	0.1	1.0
Ca+Mg	(me/100g)					
1:5 EXTRACT						
EC_5 @ 25°C	(mmhos/cm)	0.14	0.12	0.12	0.24	1.4
Ca+Mg	(me/l)	1.0	0.94	1.1	1.8	12.7
EXCHANGEABLE SODIUM	(percent)	0.0	0.0	0.0	0.1	5.0
ACIDITY						
IN KCl exchange acidity						
Total	(me/100g)					
Al^{+++}	(me/100g)					
CATION EXCHANGE CAPACITY	(me/100g)	18.6	17.0	14.4	12.8	11.0
NaOAc @ pH 8.2						
BORON	(mg/l)					

7-2006A (1-76)
Bureau of Reclamation

Table 4
Sheet 2 of 2

U.S. BUREAU OF RECLAMATION
POINT SITE LAND CHARACTERIZATION
(WITH DETERMINATIONS)

Study Area: Southwest Glendive, MT
Location. Sec. 22 Twp. 15N Range 53E
400' S. and 2250' E. of W½ Corner
Climate: Semi-arid
Land Use: Cropland
Point Site Number: 11

Relief: Simple, concave
Elevation: 2600 feet
Slope: Aspect: 3%, S-SE
Vegetation: Small grains
Erosion: Moderate

Stoniness: None
Drainage: Well drained
Ground Water:
Land Form: Lower sideslope

Parent Material: Alluvium
Soil Series: Farnuf (like)
Soil Classification: Fine - silty, mixed, Typic Haploboroll
Profile Description By: W. Volk Date: 7/81
Correlated By: W. Volk Date: 7/81

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION
G-174	60.0-84.0	Same description as C2.
G-175	84.0-120.0	Same description as C2.
		Greenhouse Samples G-170 - 0-11" G-171 - 11-24" G-172 - 24-38" G-173 - 38-60" G-174 - 60-84" G-175 - 84-120"

LABORATORY DESCRIPTION

DETERMINATION		DATA	
LABORATORY NUMBER		G-174	G-175
DEPTH	(in)	60-84	84-120
PARTICLE SIZE ANALYSIS	(percent)		
Very Coarse Sand	(2.0-1.0 mm)		
Coarse Sand	(1.0-0.5 mm)		
Medium Sand	(0.5-0.25 mm)		
Fine Sand	(0.25-0.10 mm)		
Very Fine Sand	(0.10-0.05 mm)		
Total Sand	(2.0-0.05 mm)	28.0	37.0
Silt	(0.05-0.002 mm)	52.0	45.4
Clay	(<0.002 mm)	20.0	17.6
TEXTURAL CLASS (LAB.)		SiL	L
BULK DENSITY	(g/cm^3)		
HYDRAULIC CONDUCTIVITY	(in/hr)		
6th hr		0.59	1.38
24th hr		0.67	1.69
SETTLING VOLUME	(ml)	21	20
MOISTURE RETENTION	(percent)		
1/10 bar			
1/3 bar		20.5	18.2
15 bar		7.6	7.0
SOIL REACTION-pH			
Paste		8.0	8.3
1:5 H_2O		8.3	8.4
1:2 0.01 M $CaCl_2$			
ORGANIC CARBON	(percent)	0.3	0.2
AVAILABLE PHOSPHORUS	(ppm)		
$CaCO_3$ EQUIVALENT	(percent)		
GYPSUM REQUIREMENT	(me/100g)		
SATURATION EXTRACT			
Saturation Percentage		35.0	33.1
EC_e @ 25°C	(mmhos/cm)	5.6	8.2
Ca^{++}	(me/l)	20.8	19.4
Mg^{++}	(me/l)	29.7	38.2
Na^+	(me/l)	26.6	50.2
K^+	(me/l)	0.3	0.3
CO_3^-	(me/l)	0.0	0.0
HCO_3^-	(me/l)	1.1	0.7
Cl^-	(me/l)	0.0	0.5
SO_4^-	(me/l)	78.0	106.0
NO_3^-	(me/l)	0.3	1.0
SAR	(me/l)	5.3	9.3
Na	(me/100g)	0.9	1.7
Ca+Mg	(me/100g)		
1:5 EXTRACT			
EC_5 @ 25°C	(mmhos/cm)	1.38	1.90
Ca+Mg	(me/l)	12.1	16.8
EXCHANGEABLE SODIUM	(percent)	7.0	9.9
ACIDITY			
1N KCl exchange acidity			
Total	(me/100g)		
Al^{+++}	(me/100g)		
CATION EXCHANGE CAPACITY	(me/100g)	9.2	8.1
NaOAc @ pH 8.2			
BORON	(mg/l)		

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U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Table 5
Sheet 1 of 2

Study Area: Upper Thirteenmile Creek, MT
Location. Sec. 6 Twp. 20N Range 53E
625' S. & 1200' W. of E¼ Corner
Climate. Semi-arid
Land Use: Rangeland
Point Site Number: 6

Relief: Concave, complex
Elevation:
Slope: Aspect: 5%; S-SW
Vegetation: Western wheatgrass, Little bluestem
Erosion: Slight

Stoniness: None
Drainage: Well drained
Ground Water:
Land Form: Concave footslope

Parent Material: Alluvium over soft shale
Soil Series: Lambert (like)
Soil Classification: Coarse-silty, mixed, frigid, Typic Ustorthent
Profile Description By: W. Volk Date: 7/81
Correlated By: W. Volk Date: 7/81

LAB AND FIELD NO.	DEPTH (Inches)		PROFILE DESCRIPTION
V-46	0.0-3.0	A1	Brown (10YR 5/3) silt loam; dark brown (10YR 4/3) moist; moderate medium granular structure; slightly hard; friable; slightly sticky; slightly plastic; slight effervescence; clear wavy boundary.
V-47	3.0-8.0	C1	Brown (10YR 5/3) silt loam; yellowish brown (10YR 5/4) moist; moderate medium prismatic structure; slightly hard; friable; slightly sticky; slightly plastic; violent effervescence; gradual wavy boundary.
V-48	8.0-27.0	C2k	Light yellowish brown (10YR 6/4) silt loam; yellowish brown (10YR 5/4) moist; weak coarse angular blocky structure; slightly hard; friable; slightly sticky; slightly plastic; violent effervescence; gradual wavy boundary.
G-161	27.0-52.0	C3r	Light gray (10YR 7/2) weathered silty shale; light brownish gray (10YR 6/2) moist; weak thin platy structure; hard; friable; slightly sticky; slightly plastic; strong effervescence.
G-162	52.0-76.0		Same description as for C3r

LABORATORY DESCRIPTION

DETERMINATION		DATA				
LABORATORY NUMBER		V-46	V-47	V-48	G-161	G-162
DEPTH	(in)	0-3	3-8	8-27	27-52	52-76
PARTICLE SIZE ANALYSIS	(percent)					
Very Coarse Sand	(2.0-1.0 mm)					
Coarse Sand	(1.0-0.5 mm)					
Medium Sand	(0.5-0.25 mm)					
Fine Sand	(0.25-0.10 mm)					
Very Fine Sand	(0.10-0.05 mm)					
Total Sand	(2.0-0.05 mm)	31.9	15.6	14.7	0.7	2.8
Silt	(0.05-0.002 mm)	55.7	68.5	67.9	91.3	86.6
Clay	(< 0.002 mm)	12.4	15.9	17.4	8.0	10.6
TEXTURAL CLASS (LAB)		SiL	SiL	SiL	Si	Si
BULK DENSITY	(g/cm^3)					
HYDRAULIC CONDUCTIVITY	(in/hr)					
6th hr		2.76	1.97	0.75	0.31	0.16
24th hr		3.31	2.36	0.75	0.31	0.18
SETTLING VOLUME	(ml)	22	22	22	17	20
MOISTURE RETENTION	(percent)					
1/10 bar						
1/3 bar		16.7	17.5	20.4	20.2	24.6
15 bar		7.5	8.2	6.3	3.8	5.1
SOIL REACTION-pH						
Paste		8.0	8.1	8.5	8.5	8.3
1:5 H_2O		8.4	7.9	8.3	8.9	8.8
1:2 0.01 M $CaCl_2$						
ORGANIC CARBON	(percent)	1.9	1.8	0.4	0.1	0.1
AVAILABLE PHOSPHORUS	(ppm)					
$CaCO_3$ EQUIVALENT	(percent)					
GYPSUM REQUIREMENT	(me/100g)					
SATURATION EXTRACT						
Saturation Percentage		47.2	48.7	38.9	50.1	39.9
EC_e @ 25°C	(mmhos/cm)	0.46	0.38	0.68	3.4	4.4
Ca^{++}	(me/l)	2.9	2.5	1.2	4.6	7.1
Mg^{++}	(me/l)	1.0	1.0	4.4	26.9	32.3
Na^+	(me/l)	0.1	0.1	0.6	11.1	18.1
K^+	(me/l)	0.4	0.3	0.3	0.4	0.3
CO_3^-	(me/l)	0.0	0.0	0.0	0.0	0.0
HCO_3^-	(me/l)	3.2	3.2	3.0	1.2	0.9
Cl^-	(me/l)	0.0	0.0	0.0	0.0	0.0
SO_4^-	(me/l)	0.4	0.4	3.1	44.0	57.0
NO_3^-	(me/l)	0.6	0.0	0.0	0.0	0.0
SAR	(me/l)	0.1	0.1	0.4	2.8	4.1
Na	(me/100g)	0.0	0.0	0.0	0.6	0.7
Ca+Mg	(me/100g)					
1:5 EXTRACT						
EC_5 @ 25°C	(mmhos/cm)	0.13	0.12	0.15	0.56	0.66
Ca+Mg	(me/l)	0.9	1.0	1.3	3.3	3.9
EXCHANGEABLE SODIUM	(percent)	0.0	0.0	0.9	1.9	6.0
ACIDITY						
IN KCl exchange acidity						
Total	(me/100g)	12.1	13.8	7.9	5.3	
Al^{+++}	(me/100g)					
CATION EXCHANGE CAPACITY	(me/100g)					6.7
NaOAc@pH 8.2						
BORON	(mg/l)					

Table 5
Sheet 2 of 2

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U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Study Area: Upper Thirteenmile Creek, MT
Location. Sec. 6 Twp. 20N Range 53E
625' S. & 1200' W. of E¼ Corner
Climate: Semi-arid
Land Use: Rangeland
Point Site Number: 6

Relief: Concave, complex
Elevation:
Slope: Aspect: 5%; S-SW
Vegetation: Western wheatgrass, Little bluestem
Erosion: Slight

Stoniness: None
Drainage: Well drained
Ground Water:
Land Form: Concave footslope

Parent Material: Alluvium over soft shale
Soil Series: Lambert (like)
Soil Classification: Coarse-silty, mixed, frigid, Typic Ustorthent
Profile Description By: W. Volk Date: 7/81
Correlated By: W. Volk Date: 7/81

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION	
G-163	76.0-100.0		Same description as for C3r
G-164	100.0-120.0	C4r	Weathered silty shale.

Greenhouse Samples

G-159 - 0-8"
G-160 - 8-27"
G-161 - 27-52"
G-162 - 52-76"
G-163 - 76-100"
G-164 - 100-120"

LABORATORY DESCRIPTION

DETERMINATION		DATA	
LABORATORY NUMBER		G-163	G-164
DEPTH	(in)	76-100	100-120
PARTICLE SIZE ANALYSIS	(percent)		
Very Coarse Sand	(2.0-1.0mm)		
Coarse Sand	(1.0-0.5mm)		
Medium Sand	(0.5-0.25mm)		
Fine Sand	(0.25-0.10mm)		
Very Fine Sand	(0.10-0.05mm)		
Total Sand	(2.0-0.05mm)	1.0	0.7
Silt	(0.05-0.002mm)	87.6	65.6
Clay	(<0.002 mm)	11.4	33.7
TEXTURAL CLASS (LAB.)		Si	SiCL
BULK DENSITY	(g/cm^3)		
HYDRAULIC CONDUCTIVITY	(in/hr)		
6th hr		0.12	0.16
24th hr		0.12	0.18
SETTLING VOLUME	(ml)	21	31
MOISTURE RETENTION	(percent)		
1/10 bar			
1/3 bar		27.3	28.2
15 bar		5.6	12.9
SOIL REACTION-pH			
Paste		8.3	8.2
1:5 H_2O		8.7	8.3
1:2 0.01 M $CaCl_2$			
ORGANIC CARBON	(percent)	0.2	0.2
AVAILABLE PHOSPHORUS	(ppm)		
$CaCO_3$ EQUIVALENT	(percent)		
GYPSUM REQUIREMENT	(me/100g)		
SATURATION EXTRACT			
Saturation Percentage		40.5	49.8
EC_e @ 25°C	(mmhos/cm)	5.6	7.0
Ca^{++}	(me/l)	0.9	20.5
Mg^{++}	(me/l)	47.3	61.6
Na^+	(me/l)	22.4	21.0
K^+	(me/l)	0.4	0.5
CO_3^-	(me/l)	0.0	0.0
HCO_3^-	(me/l)	0.7	0.7
Cl^-	(me/l)	1.4	1.8
SO_4^-	(me/l)	80.0	104.0
NO_3^-	(me/l)	0.1	0.1
SAR	(me/l)	4.6	3.3
Na	(me/100g)	0.9	1.0
Ca+Mg	(me/100g)		
1:5 EXTRACT			
EC_5 @ 25°C	(mmhos/cm)	0.80	2.0
Ca+Mg	(me/l)	5.3	21.2
EXCHANGEABLE SODIUM	(percent)	4.1	4.1
ACIDITY			
IN KCl exchange acidity			
Total	(me/100g)		
Al^{+++}	(me/100g)		
CATION EXCHANGE CAPACITY	(me/100g)	7.3	13.5
NaOAc@pH B.2			
BORON	(mg/l)		

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U.S. BUREAU OF RECLAMATION

POINT SITE LAND CHARACTERIZATION

(WITH DETERMINATIONS)

Table 6
Sheet 1 of 2

Study Area: Upper Thirteenmile Creek, MT
Location. Sec. 8 Twp. 20N Range 53E
1200' N. & 800' E. of S¼ Corner
Climate. Semi-arid
Land Use: Cropland
Point Site Number: 9

Relief: Simple, concave
Elevation:
Slope: Aspect: 2%, S-SE
Vegetation: Small grains
Erosion: Slight - Moderate

Stoniness: None
Drainage: Well drained
Ground Water:
Land Form: Terrace sideslope

Parent Material: Alluvium/shale
Soil Series: Shambo (like)
Soil Classification: Coarse-silty, mixed, Typic Haploboroll
Profile Description By: W. Volk Date: 7/81
Correlated By: W. Volk Date: 7/81

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION	
V-50	0.0-6.0	Ap1	Dark brown (10YR 4/3) loam; dark brown (10YR 3/3) moist; moderate fine granular structure; soft; very friable; slightly sticky; slightly plastic; noneffervescent; clear smooth boundary.
V-51	6.0-9.0	Ap2	Dark brown (10YR 4/3) loam; very dark grayish brown moist; moderate fine and medium granular structure; soft; very friable; slightly sticky; slightly plastic; noneffervescent; clear smooth boundary.
V-52	9.0-17.0	B2	Brown (10YR 5/3) loam; dark brown (10YR 4/3) moist; moderate medium prismatic structure; slightly hard; very friable; slightly sticky; slightly plastic; slight effervescence; clear smooth boundary.
V-53	17.0-25.0	B3k	Pale brown (10YR 6/3) loam; yellowish brown (10YR 5/4) moist; weak medium prismatic structure; slightly hard; very friable; slightly sticky; slightly plastic; violent effervescence; gradual wavy boundary.
V-54	25.0-60.0	C1k	Pale brown (10YR 5/3) clay loam; brown (10YR 5/3) moist; massive; slightly hard; very friable; slightly sticky; slightly plastic; strong effervescence.

LABORATORY DESCRIPTION

DETERMINATION		DATA				
LABORATORY NUMBER		V-50	V-51	V-52	V-53	V-54
DEPTH	(in)	0-6	6-9	9-17	17-25	25-60
PARTICLE SIZE ANALYSIS	(percent)					
Very Coarse Sand	(2.0-1.0 mm)					
Coarse Sand	(1.0-0.5 mm)					
Medium Sand	(0.5-0.25 mm)					
Fine Sand	(0.25-0.10 mm)					
Very Fine Sand	(0.10-0.05 mm)					
Total Sand	(2.0-0.05 mm)	40.5	29.5	5.8	8.3	3.8
Silt	(0.05-0.002 mm)	47.1	55.5	77.0	71.9	75.3
Clay	(< 0.002 mm)	12.4	15.0	17.2	19.8	20.9
TEXTURAL CLASS (LAB.)		L	SiL	SiL	SiL	SiL
BULK DENSITY	(g/cm^3)					
HYDRAULIC CONDUCTIVITY	(in/hr)					
6th hr		0.79	1.50	1.73	1.10	1.13
24th hr		0.87	1.81	1.81	1.26	1.34
SETTLING VOLUME	(ml)	18	19	21	21	26
MOISTURE RETENTION	(percent)					
1/10 bar						
1/3 bar		16.6	17.1	16.9	21.6	20.3
15 bar		4.2	7.5	7.4	9.3	8.8
SOIL REACTION-pH						
Paste		7.8	8.0	7.9	8.3	8.3
1:5 H_2O		8.1	8.0	8.1	8.6	8.8
1:2 0.01 M $CaCl_2$						
ORGANIC CARBON	(percent)	1.3	1.3	1.2	1.0	0.8
AVAILABLE PHOSPHORUS	(ppm)					
$CaCO_3$ EQUIVALENT	(percent)					
GYPSUM REQUIREMENT	(me/100g)					
SATURATION EXTRACT						
Saturation Percentage		33.2	37.0	40.7	41.7	39.2
EC_e @ 25°C	(mmhos/cm)	1.00	0.58	0.38	0.54	0.92
Ca^{++}	(me/l)	6.3	3.8	2.4	2.8	3.1
Mg^{++}	(me/l)	1.6	0.9	0.8	1.5	3.4
Na^{+}	(me/l)	0.2	0.2	0.1	0.4	1.9
K^{+}	(me/l)	0.4	0.1	0.0	0.0	0.0
CO_3^{-}	(me/l)	0.0	0.0	0.0	0.0	0.0
HCO_3^{-}	(me/l)	1.5	1.2	1.1	1.2	1.2
Cl^{-}	(me/l)	0.0	0.0	0.0	0.0	0.0
SO_4^{-}	(me/l)	1.2	0.4	0.5	1.5	2.7
NO_3^{-}	(me/l)	5.8	3.2	1.8	2.1	4.1
SAR	(me/l)	0.1	0.1	0.1	0.3	1.1
Na	(me/100g)	0.0	0.0	0.0	0.0	0.1
Ca+Mg	(me/100g)					
1:5 EXTRACT						
EC_5 @ 25°C	(mmhos/cm)	0.10	0.10	0.10	0.14	0.19
Ca+Mg	(me/l)	0.6	0.8	0.6	1.24	1.39
EXCHANGEABLE SODIUM	(percent)	0.0	0.0	0.0	0.7	0.8
ACIDITY						
IN KCl exchange acidity						
Total	(me/100g)					11.5
Al^{+++}	(me/100g)					
CATION EXCHANGE CAPACITY	(me/100g)					
NaOAc@pH 8.2		16.1	15.6	15.8	13.0	
BORON	(mg/l)					

Table 6
Sheet 2 of 2

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Bureau of Reclamation

U.S. BUREAU OF RECLAMATION
POINT SITE LAND CHARACTERIZATION
(WITH DETERMINATIONS)

Study Area: Upper Thirteenmile Creek, MT
Location. Sec. 8 Twp. 20N Range 53E.
1200' N. & 800' E. of S¼ Corner
Climate: Semi-arid
Land Use: Cropland
Point Site Number: 9

Relief: Simple, concave
Elevation:
Slope: Aspect: 2%, S-SE
Vegetation: Small grains
Erosion: Slight - Moderate

Stoniness: None
Drainage: Well drained
Ground Water:
Land Form: Terrace sideslope

Parent Material: Alluvium/shale
Soil Series: Shambo (like)
Soil Classification: Coarse-silty, mixed Typic Haploboroll
Profile Description By: W. Volk Date: 7/81
Correlated By: W. Volk Date: 7/81

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION	
G-168	60.0-78.0	C2	Not logged
G-169	78.0-120.0	C3r	Weathered; silty shale; not logged; lignite zone 112"-120".
			Greenhouse Samples
			G-165 - 0-17"
			G-166 - 17-36"
			G-167 - 36-54"
			G-168 - 54-78"
			G-169 - 78-108"

LABORATORY DESCRIPTION

DETERMINATION		DATA	
LABORATORY NUMBER		G-168	G-169
DEPTH	(in)	60-78	78-108
PARTICLE SIZE ANALYSIS	(percent)		
Very Coarse Sand	(2.0-1.0 mm)		
Coarse Sand	(1.0-0.5 mm)		
Medium Sand	(0.5-0.25 mm)		
Fine Sand	(0.25-0.10 mm)		
Very Fine Sand	(0.10-0.05 mm)		
Total Sand	(2.0-0.05 mm)	1.6	4.3
Silt	(0.05-0.002 mm)	64.7	60.5
Clay	(< 0.002 mm)	33.7	35.2
TEXTURAL CLASS (LAB)		SiCL	SiCL
BULK DENSITY	(g/cm^3)		
HYDRAULIC CONDUCTIVITY	(in/hr)		
6th hr		1.17	0.43
24th hr		0.87	0.43
SETTLING VOLUME	(ml)	24	30
MOISTURE RETENTION	(percent)		
1/10 bar			
1/3 bar		25.0	28.4
15 bar		11.4	12.3
SOIL REACTION-pH			
Paste		8.5	8.5
1:5 H_2O		8.9	8.9
1:2 0.01 M $CaCl_2$			
ORGANIC CARBON	(percent)	0.4	0.3
AVAILABLE PHOSPHORUS	(ppm)		
$CaCO_3$ EQUIVALENT	(percent)		
GYPSUM REQUIREMENT	(me/100g)		
SATURATION EXTRACT			
Saturation Percentage		48.7	42.4
EC_e @ 25°C	(mmhos/cm)	4.2	5.2
Ca^{++}	(me/l)	3.2	7.4
Mg^{++}	(me/l)	33.5	42.1
Na^+	(me/l)	13.9	17.9
K^+	(me/l)	0.2	0.4
CO_3^-	(me/l)	0.0	0.0
HCO_3^-	(me/l)	1.6	1.2
Cl^-	(me/l)	0.8	2.6
SO_4^-	(me/l)	48.0	64.5
NO_3^-	(me/l)	1.6	1.6
SAR	(me/l)	3.2	3.6
Na	(me/100g)	0.7	0.8
Ca+Mg	(me/100g)		
1:5 EXTRACT			
EC_5 @ 25°C	(mmhos/cm)	0.66	0.98
Ca+Mg	(me/l)	4.1	6.4
EXCHANGEABLE SODIUM	(percent)		
ACIDITY			
IN KCl exchange acidity			
Total	(me/100g)	13.9	13.0
Al^{+++}	(me/100g)		
CATION EXCHANGE CAPACITY	(me/100g)		
NaOAc@pH 8.2			
BORON	(mg/l)		

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U.S. BUREAU OF RECLAMATION
POINT SITE LAND CHARACTERIZATION
(WITH DETERMINATIONS)

Table 7
Sheet 1 of 2

Study Area: EMRIA - WOODSON PRLA, MT
Location. Sec. 4 Twp. 20N Range 56E
475' N. and 2050' W. of E½
Climate: Continental, Semi-arid
Land Use: Rangeland
Point Site Number: 8

Relief: Complex, undulating
Elevation: 2680 feet
Slope: Aspect: 5%, N-NE
Vegetation: Western wheatgrass, Blue grama
Erosion: Slight

Stoniness: None
Drainage: Well drained
Ground Water:
Land Form: Dissected alluvial fan

Parent Material: Alluvium
Soil Series: Alona
Soil Classification: Fine-silty, mixed, Borollic Camborthid
Profile Description By: W. Volk Date: 8/81
Correlated By: W. Volk Date: 8/81

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION	
G-213 4232	0.0-5.5	A1:	Brown (10YR 5/3) loam; dark grayish brown (10YR 4/2) moist; moderate fine granular structure; soft; very friable; slightly sticky; slightly plastic; strong effervescence; clear wavy boundary.
V-65 4226	5.5-10.5	B2:	Pale yellow (2.5Y 7/4) silt loam; light yellowish brown (2.5Y 6/4) moist; moderate medium prismatic structure breaks to moderate medium angular blocky; slightly hard; friable; slightly sticky; slightly plastic; strong effervescence; clear wavy boundary.
V-66 4231	10.5-24.0	B3:	Pale yellow (10YR 7/4) silt loam; light yellowish brown (10YR 6/4) moist; weak coarse prismatic structure parts to moderate medium angular blocky; slightly hard; friable; slightly sticky; slightly plastic; violent effervescence; gradual wavy boundary.
G-215 4229	24.0-42.0	C1:	Pale yellow (10YR 7/4) silt loam; light olive brown (10YR 5/4) moist; moderate coarse angular blocky structure; slightly hard; friable; slightly sticky; slightly plastic; violent effervescence; gradual wavy boundary.
G-216 4230	42.0-58.0		Same description as C1.
G-217 4227	58.0-90.0	C2:	Pale yellow (10YR 7/4) silt loam; light olive brown (10YR 5/4) moist; massive; slightly hard; friable; slightly sticky; slightly plastic; violent effervescence.

LABORATORY DESCRIPTION

DETERMINATION		DATA					
LABORATORY NUMBER		4232	4226	4231	4229	4230	4227
DEPTH	(in)	0-5.5	4.4-10.5	10.5-24.0	24.0-42.0	42.0-58.0	58.0-90.0
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)	0.0	0.0	0.0	0.0	0.0	0.0
Coarse Sand	(1.0-0.5 mm)	0.1	0.0	0.0	0.1	0.1	0.4
Medium Sand	(0.5-0.25 mm)	0.3	0.2	0.0	0.3	0.2	1.8
Fine Sand	(0.25-0.10 mm)	1.6	1.3	0.8	3.3	1.3	4.9
Very Fine Sand	(0.10-0.05 mm)	14.2	9.7	6.5	15.5	0.2	19.2
Total Sand	(2.0-0.05 mm)	16.2	11.2	7.3	19.2	1.8	26.3
Silt	(0.05-0.002 mm)	67.8	67.4	67.7	63.5	75.8	55.7
Clay	(< 0.002 mm)	16.0	21.4	25.0	17.3	22.4	18.0
TEXTURAL CLASS (LAB.)		SiL	SiL	SiL	SiL	SiL	SiL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in / hr)						
6th hr		0.39	0.12	0.20	0.14	0.02	0.28
24th hr		0.37	0.14	0.22	0.14	0.02	0.33
SETTLING VOLUME	(ml)	18	20	22	19	21	19
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar		23.4	25.0	25.9	19.7	23.8	19.3
15 bar		10.9	9.4	10.3	7.0	8.5	7.3
SOIL REACTION-pH							
Paste		7.7	7.8	8.3	9.0	8.9	8.6
1:5 H_2O		8.4	8.6	8.9	9.4	9.3	8.8
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)	2.3					
AVAILABLE PHOSPHORUS	(ppm)						
$CaCO_3$ EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me / 100g)						
SATURATION EXTRACT							
Saturation Percentage		47.5	43.7	44.6	37.0	40.6	34.8
EC_e @ 25°C	(mmhos/cm)	0.68	0.70	4.20	14.00	17.00	19.00
Ca^{++}	(me / l)	4.60	3.90	7.70	18.90	24.20	33.50
Mg^{++}	(me / l)	1.30	2.50	17.50	84.90	95.40	103.50
Na^+	(me / l)	0.10	0.70	24.40	121.90	149.20	161.80
K^+	(me / l)	0.50	0.20	0.20	0.70	0.70	0.60
CO_3^-	(me / l)	0.00	0.00	0.00	0.00	0.00	0.00
HCO_3^-	(me / l)	6.00	3.20	2.50	1.40	1.20	1.00
Cl^-	(me / l)	0.01	0.01	2.50	4.80	5.40	5.40
SO_4^-	(me / l)	0.60	4.40	45.20	224.60	270.90	303.20
NO_3^-	(me / l)	0.10	0.10	0.10	0.10	0.20	0.50
SAR	(me / l)	0.10	0.40	6.90	16.90	19.30	19.50
Na	(me / 100g)	0.10	0.10	1.10	4.50	6.10	5.60
Ca+Mg	(me / 100g)	0.30	0.30	1.10	3.80	4.90	4.80
1:5 EXTRACT							
EC_5 @ 25°C	(mmhos/cm)	0.14	0.16	0.62	1.80	2.30	3.20
Ca+Mg	(me / l)	1.50	1.66	2.72	7.39	8.31	23.55
EXCHANGEABLE SODIUM	(percent)	0.10	0.90	6.80	20.90	26.70	22.40
ACIDITY							
1N KCl exchange acidity							
Total	(me / 100g)						
Al^{+++}	(me / 100g)						
CATION EXCHANGE CAPACITY	(me / 100g)	18.5	11.7	11.7	8.6	8.6	7.6
NaOAc@pH 8.2							
BORON	(mg / l)						

Table 7
Sheet 2 of 2

7-2006A (1-76)
Bureau of Reclamation

U.S. BUREAU OF RECLAMATION
POINT SITE LAND CHARACTERIZATION
(WITH DETERMINATIONS)

Study Area: EMRIA - WOODSON PRLA, MT
Location. Sec. 4 Twp. 20N Range 56E
475' N. and 2050' W. of E¼
Climate: Continental, Semi-arid
Land Use: Rangeland
Point Site Number: 8 (cont.)

Relief: Complex, undulating
Elevation: 2680 feet
Slope: Aspect: 5% N-NE
Vegetation: Western wheatgrass, Blue grama
Erosion: Slight

Stoniness: None
Drainage: Well drained
Ground Water:
Land Form: Dissected alluvial fan

Parent Material: Alluvium
Soil Series: Alona
Soil Classification: Fine-silty, mixed, Borollic Camborthid
Profile Description By: W. Volk Date: 3/81
Correlated By: W. Volk Date: 3/81

LAB AND FIELD NO.	DEPTH (Inches)	PROFILE DESCRIPTION
G-218 4228	90.0-120.0	Same description as C2. Greenhouse Samples G-213 - 0-5" G-214 - 5-24" G-215 - 24-42" G-216 - 42-58" G-217 - 58-90" G-218 - 90-120"

LABORATORY DESCRIPTION

DETERMINATION		DATA
LABORATORY NUMBER		4228
DEPTH	(in)	90-120
PARTICLE SIZE ANALYSIS	(percent)	
Very Coarse Sand	(2.0-1.0 mm)	0.2
Coarse Sand	(1.0-0.5 mm)	1.2
Medium Sand	(0.5-0.25 mm)	3.8
Fine Sand	(0.25-0.10 mm)	5.7
Very Fine Sand	(0.10-0.05 mm)	16.6
Total Sand	(2.0-0.05 mm)	27.5
Silt	(0.05-0.002 mm)	54.0
Clay	(< 0.002 mm)	18.5
TEXTURAL CLASS (LAB.)		SiL
BULK DENSITY	(g/cm^3)	
HYDRAULIC CONDUCTIVITY	(in/hr)	
6th hr		0.18
24th hr		0.24
SETTLING VOLUME	(ml)	20
MOISTURE RETENTION	(percent)	
1/10 bar		
1/3 bar		20.2
15 bar		8.1
SOIL REACTION-pH		
Paste		8.7
1:5 H_2O		8.9
1:2 0.01 M $CaCl_2$		
ORGANIC CARBON	(percent)	
AVAILABLE PHOSPHORUS	(ppm)	
$CaCO_3$ EQUIVALENT	(percent)	
GYPSUM REQUIREMENT	(me/100g)	
SATURATION EXTRACT		
Saturation Percentage		36.9
EC_e @ 25°C	(mmhos/cm)	22.0
Ca^{++}	(me/l)	32.9
Mg^{++}	(me/l)	98.7
Na^+	(me/l)	173.3
K^+	(me/l)	0.5
CO_3^-	(me/l)	0.0
HCO_3^-	(me/l)	0.9
Cl^-	(me/l)	5.0
SO_4^-	(me/l)	304.2
NO_3^-	(me/l)	1.0
SAR	(me/l)	21.4
Na	(me/100g)	6.4
Ca+Mg	(me/100g)	4.9
1:5 EXTRACT		
EC_5 @ 25°C	(mmhos/cm)	3.2
Ca+Mg	(me/l)	20.87
EXCHANGEABLE SODIUM	(percent)	23.5
ACIDITY		
1N KCl exchange acidity		
Total	(me/100g)	
Al^{+++}	(me/100g)	
CATION EXCHANGE CAPACITY	(me/100g)	8.1
NaOAc@pH 8.2		
BORON	(mg/l)	

Table 11
Sheet 1 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA
SOIL ANALYSIS DATA SHEET
Drill Hole 81 - 101

Study Area: Woodson PRLA, Mt
Location. Sec. 4 Twp. 20N Range 56E
300' N. of SE Corner
Climate:
Land Use:
Relief:
Elevation:
Slope Aspect:
Vegetation:
Erosion:
Stoniness:
Drainage:
Cround Water:
Land Form:
Parent Material:
Soil Series:
Soil Classification:
Profile Description By: L. Parish Date:

DETERMINATION		DATA (mg/l)					
Laboratory Number		3795	3796	3797	3798	3799	3800
Sack Number		101-1	101-2	101-3	101-4	101-5	101-6
Depth		10.0-28.0	28.0-44.0	44.0-60.0	60.0-76.0	76.0-80.0	80.0-84.5
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B	0.43	0.35	0.37	0.40	0.65	0.057
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.07	0.06	0.05	0.01	0.04	0.03
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	0.30	0.27	0.12	0.33	2.39	0.55
IRON	Fe	2.30	1.80	3.10	3.20	39.3	33.9
MERCURY	Hg	0.44	0.03	0.033	0.042	0.061	0.066
LITHIUM	Li						
MANGANESE	Mn	0.82	1.06	1.32	1.35	2.63	0.90
MOLYBDENUM	Mo	0.05	0.02	0.01	0.04	0.43	0.11
NICKEL	Ni	0.15	0.06	0.08	0.10	0.95	0.37
PHOSPHOROUS	P						
LEAD	Pb	0.80	0.36	0.25	0.58	1.89	0.70
STRONTIUM	Sr						
SELENIUM	Se	0.04	0.01	0.01	0.00	0.00	0.01
VANADIUM	V						
ZINC	Zn	0.30	0.35	0.71	0.14	2.60	1.76

LABORATORY DESCRIPTION

DETERMINATION		DATA					
Laboratory Number		3795	3796	3797	3798	3799	3800
Sack Number		101-1	101-2	101-3	101-4	101-5	101-6
DEPTH	(ft)	10.1-28.0	28.0-44.0	44.0-60.0	60.0-76.0	76.0-80.0	80.0-84.5
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)						
Coarse Sand	(1.0-0.5 mm)						
Medium Sand	(0.5-0.25 mm)						
Fine Sand	(0.25-0.10 mm)						
Very Fine Sand	(0.10-0.05 mm)						
TOTAL SAND	(2.0-0.05 mm)	20.5	14.6	4.2	3.6	2.7	38.5
SILT	(0.05-0.002 mm)	59.3	70.8	79.1	75.0	61.6	54.9
CLAY	(0.002 mm)	20.2	14.6	16.7	21.4	35.7	6.6
TEXTURAL CLASS (LAB)		SiL	SiL	SiL	SiL	SiCL	SiL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.		0.10	0.10	0.04	0.04	0.04	0.12
24th Hr.		0.12	0.08	0.06	0.04	0.04	0.10
SETTLING VOLUME	(ml)	24	26	28	33	50	21
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar		8.6	6.3	6.7	9.3	13.0	6.8
SOIL REACTION-pH							
Paste							
1:5 H_2O		8.4	8.6	8.6	8.6	8.8	8.2
1:2 0.01 M $CaCl_2$		8.0	8.5	7.9	7.9	7.1	7.9
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
Ca CO_3 EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	1.2	0.0	0.0	0.4	1.0	0.8
SATURATION EXTRACT							
Saturation Percentage		41.9	43.0	42.40	47.60	55.5	34.8
EC_e@ 25°C	(mmhos/cm)	8.0	6.50	5.00	4.00	4.50	5.00
Ca++	(me/l)	22.90	17.97	14.37	9.50	17.79	9.81
Mg++	(me/l)	64.73	45.46	35.49	27.53	36.10	20.86
Na+	(me/l)	30.10	24.47	16.98	17.84	21.46	27.74
K+	(me/l)	0.48	0.60	0.61	0.57	1.26	1.16
CO_3-	(me/l)	0.00	0.00	0.00	0.00	0.00	0.00
HCO_3-	(me/l)	0.97	0.77	1.12	1.07	3.02	1.38
Cl-	(me/l)	1.24	0.76	0.32	0.28	0.14	0.10
SO_4-	(me/l)	112.00	81.00	64.00	54.00	71.00	56.00
NO_3-	(me/l)	4.8	1.50	0.98	0.59	0.03	0.01
SAR	(me/l)	4.5	4.30	3.40	4.20	4.10	7.10
Na	(me/100g)	1.3	1.05	0.70	0.80	1.20	1.00
Ca+Mg	(me/100g)	3.7	2.73	2.10	1.80	3.00	1.10
1:5 EXTRACT							
EC_5@ 25°C	(mmhos/cm)	1.80	0.83	0.71	0.70	0.99	0.51
Ca+Mg	(me/l)	16.00	4.95	4.51	3.63	5.61	1.81
EXCHANGEABLE SODIUM	(percent)	5.5	5.3	5.6	5.0	5.00	9.0
ACIDITY							
1N KCL exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	9.3	7.2	7.0	9.2	11.5	3.9
NaOAc@pH 8.2							
BORON	(mg/l)						

Table II
Sheet 2of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA
SOIL ANALYSIS DATA SHEET
Drill Hole 81 - 101 (cont'd)

Study Area: Woodson PRLA, Mt
Relief:
Stoniness:
Parent Material:
Location. Sec. 4 Twp. 20N Range 56E
Elevation:
Soil Series:
300' N. of SE Corner
Slope Aspect:
Drainage:
Soil Classification:
Climate:
Vegetation:
Ground Water:
Land Use:
Erosion:
Land Form:
Profile Description By: L. Parish Date:

DETERMINATION		DATA (mg/l)
Laboratory Number		3801
Sack Number		101-7
Depth		121.2-131.0
ALUMINUM	Al	
SILVER	Ag	
ARSENIC	As	
BORON	B	0.23
BARIUM	Ba	
BERYLLIUM	Be	
CADMIUM	Cd	0.10
COBALT	Co	
CHROMIUM	Cr	
COPPER	Cu	1.92
IRON	Fe	5.60
MERCURY	Hg	0.077
LITHIUM	Li	
MANGANESE	Mn	4.00
MOLYBDENUM	Mo	0.25
NICKEL	Ni	0.96
PHOSPHOROUS	P	
LEAD	Pb	2.43
STRONTIUM	Sr	
SELENIUM	Se	0.01
VANADIUM	V	
ZINC	Zn	2.46

LABORATORY DESCRIPTION

DETERMINATION		DATA
Laboratory Number		3801
Sack Number		101-7
DEPTH	(ft)	121.2-131.0
PARTICLE SIZE ANALYSIS	(percent)	
Very Coarse Sand	(2.0-1.0 mm)	
Coarse Sand	(1.0-0.5 mm)	
Medium Sand	(0.5-0.25 mm)	
Fine Sand	(0.25-0.10 mm)	
Very Fine Sand	(0.10-0.05 mm)	
TOTAL SAND	(2.0-0.05 mm)	19.9
SILT	(0.05-0.002 mm)	61.9
CLAY	(0.002 mm)	18.2
TEXTURAL CLASS (LAB)		SiL
BULK DENSITY	(g/cm^3)	
HYDRAULIC CONDUCTIVITY	(in/hr)	
6th Hr.		0.00
24th Hr.		0.00
SETTLING VOLUME	(ml)	90
MOISTURE RETENTION	(percent)	
1/10 bar		
1/3 bar		
15 bar		12.1
SOIL REACTION-pH		
Paste		
1:5 H_2O		9.8
1:2 0.01 M $CaCl_2$		8.2
ORGANIC CARBON	(percent)	
AVAILABLE PHOSPHORUS	(ppm)	
Ca CO_3 EQUIVALENT	(percent)	
GYPSUM REQUIREMENT	(me/100g)	4.4
SATURATION EXTRACT		
Saturation Percentage		46.6
EC_e@ 25°C	(mmhos/cm)	2.20
Ca++	(me/l)	0.62
Mg++	(me/l)	0.40
Na+	(me/l)	18.59
K+	(me/l)	0.26
CO_3-	(me/l)	0.00
HCO_3-	(me/l)	4.60
Cl-	(me/l)	0.04
SO_4-	(me/l)	14.00
NO_3-	(me/l)	0.04
SAR	(me/l)	26.00
Na	(me/100g)	0.90
Ca+Mg	(me/100g)	0.10
1:5 EXTRACT		
FC_5@ 25°C	(mmhos/cm)	0.25
Ca+Mg	(me/l)	0.11
EXCHANGEABLE SODIUM	(percent)	31.55
ACIDITY		
IN KCL exchange acidity		
Total	(me/100g)	
Al+++	(me/100g)	
CATION EXCHANGE CAPACITY	(me/100g)	8.8
NaOAc@pH 8.2		
BORON	(mg/l)	

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

DRILL HOLE 81-102

Table 12
Sheet 1 of 3

Study Area: Burns Creek, Mt
Location. Sec. 30 Twp. 19N Range 56E
2650' E. & 1950' S. of NW Corner
Climate:
Land Use:
Relief:
Elevation:
Slope Aspect:
Vegetation:
Erosion:
Stoniness:
Drainage:
Ground Water:
Land Form:
Parent Material:
Soil Series:
Soil Classification:
Profile Description By: L. Parish Date:

DETERMINATION		DATA (mg/1)				
Laboratory Number		3802	3803	3804	3805	3806
Sack Number		102-1	102-2	102-3	102-4	102-5
Depth		10.0-33.6	33.6-55.0	55.0-65.5	65.6-69.0	69.0-80.0
ALUMINUM	Al					
SILVER	Ag					
ARSENIC	As					
BORON	B	0.33	0.23	0.31	0.75	0.53
BARIUM	Ba					
BERYLLIUM	Be					
CADMIUM	Cd	0.04	0.10	0.02	0.03	0.08
COBALT	Co					
CHROMIUM	Cr					
COPPER	Cu	0.24	0.36	0.60	2.23	2.20
IRON	Fe	3.80	3.70	1.20	27.30	59.80
MERCURY	Hg	0.05	0.069	0.061	0.011	0.036
LITHIUM	Li					
MANGANESE	Mn	1.92	0.68	1.25	6.80	10.36
MOLYBDENUM	Mo	0.35	0.06	0.02	0.18	0.38
NICKEL	Ni	0.18	0.13	0.10	0.74	1.80
PHOSPHOROUS	P					
LEAD	Pb	0.29	0.58	0.30	2.50	1.78
STRONTIUM	Sr					
SELENIUM	Se	0.01	0.01	0.01	0.01	0.01
VANADIUM	V					
ZINC	Zn	2.48	0.61	0.24	1.39	2.50

LABORATORY DESCRIPTION

DETERMINATION		DATA				
Laboratory Number		3802	3803	3804	3805	3806
Sack Number		102-1	102-2	102-3	102-4	102-5
DEPTH	(ft)	10.0-33.6	33.6-55.0	55.0-65.5	65.6-69.0	69.0-80.0
PARTICLE SIZE ANALYSIS	(percent)					
Very Coarse Sand	(2.0-1.0 mm)	14.5				
Coarse Sand	(1.0-0.5 mm)	15.0				
Medium Sand	(0.5-0.25 mm)	29.2				
Fine Sand	(0.25-0.10 mm)	23.8				
Very Fine Sand	(0.10-0.05 mm)	9.2				
TOTAL SAND	(2.0-0.05 mm)	91.7	4.9	21.4	9.1	2.5
SILT	(0.05-0.002 mm)	6.1	54.2	67.2	50.7	62.4
CLAY	(0.002 mm)	2.2	40.9	11.4	40.2	35.1
TEXTURAL CLASS (LAB)		S	SiC	SiL	SiC	SiCL
BULK DENSITY	(g/cm^3)					
HYDRAULIC CONDUCTIVITY	(in/hr)					
6th Hr.		4.45	0.04	0.12	0.00	0.00
24th Hr.		4.22	0.04	0.12	0.04	0.00
SETTLING VOLUME	(ml)	15	40	25	40	42
MOISTURE RETENTION	(percent)					
1/10 bar						
1/3 bar						
15 bar		1.7	15.7	5.8	16.9	13.7
SOIL REACTION-pH						
Paste						
1:5 H_2O		9.2	8.7	9.0	8.1	8.6
1:2 0.01 M $CaCl_2$		7.8	7.6	7.8	7.4	7.6
ORGANIC CARBON	(percent)					
AVAILABLE PHOSPHORUS	(ppm)					
Ca CO_3 EQUIVALENT	(percent)					
GYPSUM REQUIREMENT	(me/100g)	3.0	0.0	3.5	1.0	0.08
SATURATION EXTRACT						
Saturation Percentage		22.9	62.8	34.9	60.0	54.7
EC_e@ 25°C	(mmhos/cm)	1.20	0.34	0.38	1.80	0.95
Ca++	(me/1)	0.91	0.61	0.68	8.78	3.43
Mg++	(me/1)	2.03	1.88	2.05	9.77	4.00
Na+	(me/1)	7.08	0.50	0.68	0.97	0.84
K+	(me/1)	0.20	0.16	0.09	0.54	0.54
CO_3-	(me/1)	0.00	0.00	0.00	0.00	0.00
HCO_3-	(me/1)	3.68	1.94	1.59	4.04	4.76
Cl-	(me/1)	2.24	0.02	0.01	0.02	0.01
SO_4-	(me/1)	4.40	0.97	1.80	15.00	4.82
NO_3-	(me/1)	0.01	0.02	0.03	0.01	0.00
SAR	(me/1)	5.00	0.40	0.50	0.30	0.40
Na	(me/100g)	0.20	0.00	0.00	0.10	0.10
Ca+Mg	(me/100g)	0.10	0.20	0.10	1.10	0.40
1:5 EXTRACT						
EC_5@ 25°C	(mmhos/cm)	0.15	0.12	0.10	0.32	0.20
Ca+Mg	(me/1)	0.55	0.77	0.57	2.37	1.47
EXCHANGEABLE SODIUM	(percent)	4.7	0.50	0.90	0.40	0.40
ACIDITY						
IN KCL exchange acidity						
Total	(me/100g)					
Al+++	(me/100g)					
CATION EXCHANGE CAPACITY NaOAc@pH 8.2	(me/100g)	5.7	18.8	6.4	23.1	14.0
BORON	(mg/1)					

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

DRILL HOLE 81 - 102 (cont'd)

Table 12
Sheet 2 of 3

Study Area: Burns Creek, Mt
Relief:
Stoniness:
Parent Material:

Location. Sec. 30 Twp. 19N Range 56E
2650' E. & 1950' S. of NW Corner
Elevation:
Soil Series:

Slope Aspect:
Drainage:
Soil Classification:

Climate:
Vegetation:
Cround Water:

Land Use:
Erosion:
Land Form:
Profile Description By: L. Parish
Date:

DETERMINATION		DATA (mg/1)				
Laboratory Number		3807	3808	3809	3810	3811
Sack Number		102-6	102-7	102-8	102-9	102-10
Depth		80.0-105.4	106.2-125.0	125.0-141.0	141.0-147.0	147.0-167.0
ALUMINUM	Al					
SILVER	Ag					
ARSENIC	As					
BORON	B	0.42	0.60	0.56	0.62	0.54
BARIUM	Ba					
BERYLLIUM	Be					
CADMIUM	Cd	0.04	0.04	0.02	0.06	0.04
COBALT	Co					
CHROMIUM	Cr					
COPPER	Cu	2.16	2.19	2.41	0.95	1.34
IRON	Fe	53.50	58.50	45.90	16.10	42.30
MEPCURY	Hg	0.036	0.030	0.069	0.05	0.042
LITHIUM	Li					
MANGANESE	Mn	6.19	7.35	6.53	4.48	7.24
MOLYBDENUM	Mo	0.24	0.33	0.17	0.25	0.47
NICKEL	Ni	0.99	0.92	0.32	0.60	0.85
PHOSPHOROUS	P					
LEAD	Pb	1.62	1.55	2.03	0.83	1.13
STRONTIUM	Sr					
SELENIUM	Se	0.01	0.01	0.01	0.01	0.01
VANADIUM	V					
ZINC	Zn	1.49	1.66	1.86	1.51	1.64

LABORATORY DESCRIPTION

DETERMINATION		DATA				
Laboratory Number		3807	3808	3809	3810	3811
Sack Number		102-6	102-7	102-8	102-9	102-10
DEPTH	(ft)	80.0-105.4	106.2-125.0	125.0-141.0	141.0-147.0	147.0-167.0
PARTICLE SIZE ANALYSIS	(oercent)					
Very Coarse Sand	(2.0-1.0 mm)					
Coarse Sand	(1.0-0.5 mm)					
Medium Sand	(0.5-0.25 mm)					
Fine Sand	(0.25-0.10 mm)					
Very Fine Sand	(0.10-0.05 mm)					
TOTAL SAND	(2.0-0.05 mm)	3.3	10.7	10.3	17.2	0.2
SILT	(0.05-0.002 mm)	72.7	55.5	61.6	61.8	69.0
CLAY	(0.002 mm)	24.0	33.8	28.1	21.0	30.8
TEXTURAL CLASS (LAB)		SiL	SiCL	SiCL	SiL	SiCL
BULK DENSITY	(g/cm^3)					
HYDRAULIC CONDUCTIVITY	(in/hr)					
6th Hr.		0.08	0.08	0.06	0.06	0.08
24th Hr.		0.08	0.12	0.08	0.06	0.08
SETTLINC VOLUME	(ml)	31	36	35	27	33
MOISTURE RETENTION	(percent)					
1/10 bar						
1/3 bar						
15 bar		8.4	12.2	11.8	6.5	11.0
SOIL REACTION-pH						
Paste						
1:5 H_2O		8.6	8.1	8.5	8.4	8.5
1:2 0.01 M $CaCl_2$		7.7	7.5	7.9	7.5	7.6
ORCANIC CARBON	(percent)					
AVAILABLE PHOSPHORUS	(ppm)					
Ca CO_3 EQUIVALENT	(percent)					
CYPSUM REQUIREMENT	(me/100g)	1.20	4.9	1.2	1.6	1.6
SATURATION EXTRACT						
Saturation Percentage		45.1	53.4	51.9	39.5	55.6
EC_e@ 25°C	(mmhos/cm)	1.00	1.55	0.95	1.42	1.18
Ca++	(me/1)	3.21	6.56	3.13	5.47	4.18
Mg++	(me/1)	4.09	7.91	3.82	6.71	5.13
Na+	(me/1)	0.98	1.15	1.09	1.75	1.31
K+	(me/1)	0.63	0.69	0.48	0.62	0.70
CO_3-	(me/1)	0.00	0.00	0.00	0.00	0.00
HCO_3-	(me/1)	4.40	4.14	3.32	4.60	5.62
Cl-	(me/1)	0.02	0.04	0.02	0.04	0.04
SO_4-	(me/1)	5.38	13.20	5.82	10.76	6.50
NO_3-	(me/1)	0.00	0.00	0.00	0.00	0.00
SAR	(me/1)	0.50	0.40	0.60	0.70	0.60
Na	(me/100g)	0.00	0.10	0.10	0.10	0.10
Ca+Mg	(me/100g)	0.30	0.80	0.40	0.50	0.50
1:5 EXTRACT						
FC_5@ 25°C	(mmhos/cm)	0.19	0.33	0.20	0.20	0.25
Ca+Mg	(me/1)	1.21	2.30	1.22	1.24	1.57
EXCHANCEABLE SODIUM	(percent)	0.63	0.40	0.60	0.80	0.7
ACIDITY						
1N KCL exchange acidity						
Total	(me/100g)					
Al+++	(me/100g)					
CATION EXCHANCE CAPACITY	(me/100g)	7.9	12.6	10.9	10.7	10.1
NaOAc@pH 8.2						
BORON	(mg/1)					

Table 12
Sheet 3 of 3

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET
DRILL HOLE 81 - 102 (cont'd)

Study Area: Burns Creek, Mt
Relief:
Stoniness:
Parent Material:
Location. Sec. 30 Twp. 19N Range 56E
2650' E. and 1950' S. of NW Corner
Elevation:
Soil Series:
Slope Aspect:
Drainage:
Soil Classification:
Climate:
Vegetation:
Cround Water:
Land Use:
Erosion:
Land Form:
Profile Description By: L. Parish
Date:

DETERMINATION		DATA (mg/l)			
Laboratory Number		3812	3813	3814	3815
Sack Number		102-11	102-12	102-13	102-14
Depth		169.8-189.0	189.0-209.4	219.5-222.6	252.1-270.0
ALUMINUM	Al				
SILVER	Ag				
ARSENIC	As				
BORON	B	0.15	0.56	0.91	0.65
BARIUM	Ba				
BERYLLIUM	Be				
CADMIUM	Cd	0.01	0.05	0.01	0.02
COBALT	Co				
CHROMIUM	Cr				
COPPER	Cu	1.27	0.87	1.27	1.47
IRON	Fe	38.0	3.80	26.60	31.70
MEPCURY	Hg	0.077	0.058	0.053	0.058
LITHIUM	Li				
MANGANESE	Mn	6.23	1.08	6.42	7.49
MOLYBDENUM	Mo	0.20	0.23	0.15	0.27
NICKEL	Ni	0.76	1.20	0.99	0.75
PHOSPHOROUS	P				
LEAD	Pb	0.89	1.40	1.30	1.06
STRONTIUM	Sr				
SELENIUM	Se	0.01	0.01	0.01	0.01
VANADIUM	V				
ZINC	Zn	1.08	3.74	2.34	1.82

LABORATORY DESCRIPTION

DETERMINATION		DATA			
Laboratory Number		3812	3813	3814	3815
Sack Number		102-11	102-12	102-13	102-14
DEPTH	(ft)	169.8-189.0	189.0-209.4	219.5-222.6	252.1-270.0
PARTICLE SIZE ANALYSIS	(oercent)				
Very Coarse Sand	(2.0-1.0 mm)				
Coarse Sand	(1.0-0.5 mm)				
Medium Sand	(0.5-0.25 mm)				
Fine Sand	(0.25-0.10 mm)				
Very Fine Sand	(0.10-0.05 mm)				
TOTAL SAND	(2.0-0.05 mm)	0.1	1.1	24.5	5.2
SILT	(0.05-0.002 mm)	70.1	72.5	55.4	73.1
CLAY	(0.002 mm)	28.8	26.4	20.1	21.7
TEXTURAL CLASS (LAB)		SiL	SiL	SiL	SiL
BULK DENSITY	(g/cm^3)				
HYDRAULIC CONDUCTIVITY	(in/hr)				
6th Hr.		0.08	0.10	0.04	0.02
24th Hr.		0.08	0.10	0.02	0.02
SETTLINC VOLUME	(ml)	35	29	40	33
MOISTURE RETENTION	(percent)				
1/10 bar					
1/3 bar					
15 bar		11.3	10.2	8.5	9.7
SOIL REACTION-pH					
Paste					
1:5 H_2O		8.6	8.4	8.3	8.5
1:2 0.01 M $CaCl_2$		7.7	7.6	7.6	7.8
ORGANIC CARBON	(percent)				
AVAILABLE PHOSPHORUS	(ppm)				
Ca CO_3 EQUIVALENT	(percent)				
CYPSUM REQUIREMENT	(me/100g)	1.6	0.8	1.6	0.0
SATURATION EXTRACT					
Saturation Percentage		57.1	52.3	42.1	51.1
EC_e@ 25°C	(mmhos/cm)	0.90	1.18	1.02	2.10
Ca++	(me/1)	2.90	4.04	2.84	4.42
Mg++	(me/1)	3.68	4.32	3.71	5.94
Na+	(me/1)	1.37	1.83	2.6=	9.34
K+	(me/1)	0.67	0.60	0.47	0.82
CO_3-	(me/1)	0.00	0.00	0.00	0.00
HCO_3-	(me/1)	5.93	4.35	2.97	5.00
Cl-	(me/1)	0.02	0.02	0.02	0.16
SO_4-	(me/1)	3.20	8.00	7.42	16.40
NO_3-	(me/1)	0.00	0.00	0.00	0.00
SAR	(me/1)	0.80	0.90	1.40	4.10
Na	(me/100g)	0.10	0.10	0.10	0.50
Ca+Mg	(me/100g)	0.40	0.40	0.30	0.50
1:5 EXTRACT					
FC_5@ 25°C	(mmhos/cm)	0.20	0.22	0.14	0.32
Ca+Mg	(me/1)	1.16	1.39	0.73	1.09
EXCHANCEABLE SODIUM	(percent)	0.80	0.90	1.60	4.6
ACIDITY					
IN KCL exchange acidity					
Total	(me/100g)				
Al+++	(me/100g)				
CATION EXCHANCE CAPACITY	(me/100g)	10.0	10.5	8.9	8.2
NaOAc@pH 8.2					
BORON	(mg/1)				

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET
DRILL HOLE 81-103

Table 13
Sheet 1 of 3

Study Area: Burns Creek, Mt

Location. Sec. 24 Twp. 19N Range 55E

1020' N. and 2720' E. of SW Corner

Climate:

Land Use:

Relief:

Elevation:

Slope Aspect:

Vegetation:

Erosion:

Stoniness:

Drainage:

Ground Water:

Land Form:

Parent Material:

Soil Series:

Soil Classification:

Profile Description By: G. Taucher L. Parish Date:

DETERMINATION		DATA (mg/1)			
Laboratory Number		3816	3817	3818	3819
Sack Number		103-1	103-2	103-3	103-4
Depth		10.0-30.0	30.0-35.8	35.8-47.5	47.5-63.5
ALUMINUM	Al				
SILVER	Ag				
ARSENIC	As				
BORON	B	0.35		0.40	0.33
BARIUM	Ba				
BERYLLIUM	Be				
CADMIUM	Cd	0.01		0.01	0.01
COBALT	Co				
CHROMIUM	Cr				
COPPER	Cu	0.06		0.17	0.14
IRON	Fe	1.60		14.50	3.20
MEPCURY	Hg	0.042	0.047	0.036	0.051
LITHIUM	Li				
MANGANESE	Mn	0.59		4.09	0.46
MOLYBDENUM	Mo	0.25	0.26	0.14	0.11
NICKEL	Ni	0.16		0.17	0.06
PHOSPHOROUS	P				
LEAD	Pb	0.20		0.47	0.62
STRONTIUM	Sr				
SELENIUM	Se	0.01		0.01	0.01
VANADIUM	V				
ZINC	Zn	1.34		0.25	0.28

LABORATORY DESCRIPTION

DETERMINATION		DATA			
Laboratory Number		3816	3817	3818	3819
Sack Number		103-1	103-2	103-3	103-4
DEPTH	(ft)	10.0-30.0	30.0-35.8	35.8-47.5	47.5-63.5
PARTICLE SIZE ANALYSIS	(percent)				
Very Coarse Sand	(2.0-1.0 mm)	5.9	6.7		
Coarse Sand	(1.0-0.5 mm)	15.4	8.2		
Medium Sand	(0.5-0.25 mm)	24.3	22.2		
Fine Sand	(0.25-0.10 mm)	19.3	22.3		
Very Fine Sand	(0.10-0.05 mm)	22.0	14.0		
TOTAL SAND	(2.0-0.05 mm)	86.9	73.4	1.1	12.3
SILT	(0.05-0.002 mm)	12.0	21.8	64.7	55.2
CLAY	(0.002 mm)	1.1	4.8	34.2	32.5
TEXTURAL CLASS (LAB)		S	LS	SiCL	SiCL
BULK DENSITY	(g/cm^3)				
HYDRAULIC CONDUCTIVITY	(in/hr)				
6th Hr.		4.06	1.26	0.06	0.06
24th Hr.		3.78	1.42	0.06	0.06
SETTLING VOLUME	(ml)	14	17	35	32
MOISTURE RETENTION	(percent)				
1/10 bar					
1/3 bar					
15 bar		1.7	4.0	14.2	15.4
SOIL REACTION-pH					
Paste					
1:5 H_2O		8.7	8.6	8.6	8.7
1:2 0.01 M $CaCl_2$		7.9	7.6	7.7	7.7
ORGANIC CARBON	(percent)				
AVAILABLE PHOSPHORUS	(ppm)				
Ca CO_3 EQUIVALENT	(percent)				
GYPSUM REQUIREMENT	(me/100g)	1.0	2.0	3.0	0.0
SATURATION EXTRACT					
Saturation Percentage		22.0		54.4	48.0
EC_e@ 25°C	(mmhos/cm)	0.62		0.28	0.36
Ca++	(me/1)	0.96		1.20	1.20
Mg++	(me/1)	1.96		1.17	1.48
Na+	(me/1)	1.73		0.34	0.43
K+	(me/1)	0.15		0.15	0.14
CO_3-	(me/1)	0.00		0.00	0.00
HCO_3-	(me/1)	2.61		1.94	2.20
Cl-	(me/1)	0.96		0.02	0.44
SO_4-	(me/1)	2.00		0.30	0.71
NO_3-	(me/1)	0.00		0.03	0.04
SAR	(me/1)	1.40		0.30	0.40
Na	(me/100g)	0.00		0.00	0.00
Ca+Mg	(me/100g)	0.10		0.10	0.10
1:5 EXTRACT					
EC_5@ 25°C	(mmhos/cm)	0.11	0.11	0.12	0.12
Ca+Mg	(me/1)	0.50	0.57	0.91	0.90
EXCHANGEABLE SODIUM	(percent)	1.70		0.20	0.40
ACIDITY					
IN KCL exchange acidity					
Total	(me/100g)				
Al+++	(me/100g)				
CATION EXCHANGE CAPACITY	(me/100g)	4.1	7.9	15.4	17.1
NaOAc@pH 8.2					
BORON	(mg/1)				

Table 13
Sheet 2 of 3

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA
SOIL ANALYSIS DATA SHEET
DRILL HOLE 81-103 (cont'd)

Study Area: Burns Creek, Mt
Location. Sec. 24 Twp. 19N Range 55E
1020' N. & 2720' E. of SW Corner
Climate:
Land Use:
Relief:
Elevation:
Slope Aspect:
Vegetation:
Erosion:
Stoniness:
Drainage:
Ground Water:
Land Form:
Parent Material:
Soil Series:
Soil Classification:
Profile Description By: G. Taucher L. Parish Date:

DETERMINATION		DATA (mg/l)			
Laboratory Number		3820	3821	3822	3823
Sack Number		103-5	103-6	103-7	103-8
Depth		63.5-77.0	77.0-88.2	88.2-110.3	110.3-133.8
ALUMINUM	Al				
SILVER	Ag				
ARSENIC	As				
BORON	B	0.33	0.63	0.41	0.54
BARIUM	Ba				
BERYLLIUM	Be				
CADMIUM	Cd	0.01	0.02	0.08	0.03
COBALT	Co				
CHROMIUM	Cr				
COPPER	Cu	1.24	1.74	1.23	1.83
IRON	Fe	3.00	41.2	27.50	29.10
MERCURY	Hg	0.044	0.050	0.072	0.078
LITHIUM	Li				
MANGANESE	Mn	1.25	12.27	6.00	6.09
MOLYBDENUM	Mo	0.08	0.66	0.19	0.31
NICKEL	Ni	0.02	1.36	0.72	1.07
PHOSPHOROUS	P				
LEAD	Pb	0.56	1.47	1.29	1.52
STRONTIUM	Sr				
SELENIUM	Se	0.01	0.01	0.01	0.01
VANADIUM	V				
ZINC	Zn	0.21	2.63	1.25	1.76

LABORATORY DESCRIPTION

DETERMINATION		DATA			
Laboratory Number		3820	3821	3822	3823
Sack Number		103-5	103-6	103-7	103-8
DEPTH	( )	63.5-77.0	77.0-88.2	88.2-110.3	110.3-133.8
PARTICLE SIZE ANALYSIS	(percent)				
Very Coarse Sand	(2.0-1.0 mm)				
Coarse Sand	(1.0-0.5 mm)				
Medium Sand	(0.5-0.25 mm)				
Fine Sand	(0.25-0.10 mm)				
Very Fine Sand	(0.10-0.05 mm)				
TOTAL SAND	(2.0-0.05 mm)	3.2	0.2	0.4	0.6
SILT	(0.05-0.002 mm)	69.2	52.1	77.4	55.1
CLAY	(0.002 mm)	27.0	47.7	22.2	44.3
TEXTURAL CLASS (LAB)		SiCL	SiC	SiL	SiC
BULK DENSITY	(g/cm^3)				
HYDRAULIC CONDUCTIVITY	(in/hr)				
6th Hr.		0.06	0.06	0.02	0.02
24th Hr.		0.06	0.08	0.02	0.06
SETTLING VOLUME	(ml)	35	45	36	47
MOISTURE RETENTION	(percent)				
1/10 bar					
1/3 bar					
15 bar		10.8	17.6	8.3	15.2
SOIL REACTION-pH					
Paste					
1:5 H_2O		8.7	8.2	8.6	8.5
1:2 0.01 M $CaCl_2$		7.8	7.6	7.6	7.7
ORGANIC CARBON	(percent)				
AVAILABLE PHOSPHORUS	(ppm)				
Ca CO_3 EQUIVALENT	(percent)				
GYPSUM REQUIREMENT	(me/100g)	0.4	0.8	1.2	2.4
SATURATION EXTRACT					
Saturation Percentage		49.0	67.9	46.5	61.0
EC_e@ 25°C	(mmhos/cm)	0.46	1.18	1.00	1.08
Ca++	(me/l)	1.61	4.35	3.28	3.54
Mg++	(me/l)	1.79	5.63	4.28	4.48
Na+	(me/l)	0.60	0.83	0.99	1.12
K+	(me/l)	0.17	0.07	0.05	0.06
CO_3-	(me/l)	0.00	0.00	0.00	0.00
HCO_3-	(me/l)	2.20	4.04	3.63	3.12
Cl-	(me/l)	0.04	0.02	0.08	0.04
SO_4-	(me/l)	1.78	7.70	5.80	6.80
NO_3-	(me/l)	0.03	0.03	0.01	0.00
SAR	(me/l)	0.50	0.40	0.50	0.60
Na	(me/100g)	0.00	0.10	0.10	0.10
Ca+Mg	(me/100g)	0.20	0.70	0.40	0.50
1:5 EXTRACT					
EC_5@ 25°C	(mmhos/cm)	0.13	0.31	0.20	0.25
Ca+Mg	(me/l)	0.90	2.31	1.33	1.58
EXCHANGEABLE SODIUM	(percent)	0.40	0.20	0.30	0.70
ACIDITY					
1N KCL exchange acidity					
Total	(me/100g)				
Al+++	(me/100g)				
CATION EXCHANGE CAPACITY	(me/100g)	11.5	16.5	9.0	11.4
NaOAc@pH 8.2					
BORON	(mg/l)				

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET
DRILL HOLE 81-103 (cont'd)

Table 13
Sheet 3 of 3

Study Area: Burns Creek, Montana
Location. Sec. 24 Twp. 19N Range 55E
1[illegible]2[illegible]' N. and 2720' E. of SW Corner
Climate:
Land Use:
Relief:
Elevation:
Slope Aspect:
Vegetation:
Erosion:
Stoniness:
Drainage:
Cround Water:
Land Form:
Parent Material:
Soil Series:
Soil Classification:
Profile Description By: G. Taucher
L. Parish Date:

OETERMINATION		OATA (mg/l)			
Laboratory Number		3824	3825	3826	3827
Sack Number		103-9	103-10	103-11	103-12
Depth		135.0-171.0	172.3-200.5	200.5-204.0	240.0-253.0
ALUMINUM	Al				
SILVER	Ag				
ARSENIC	As				
BORON	B	0.46	0.59	0.63	0.84
BARIUM	Ba				
BERYLLIUM	Be				
CADMIUM	Cd	0.04	0.02	0.02	0.06
COBALT	Co				
CHROMIUM	Cr				
COPPER	Cu	2.00	1.35	0.88	1.99
IRON	Fe	42.60	36.20	7.10	8.00
MEPCURY	Hg	0.044	0.081	0.72	0.087
LITHIUM	Li				
MANGANESE	Mn	7.38	6.64	3.16	2.04
MOLYBDENUM	Mo	0.27	0.21	0.16	0.27
NICKEL	Ni	0.65	0.92	0.49	1.03
PHOSPHOROUS	P				
LEAD	Pb	0.93	1.04	1.76	3.27
STRONTIUM	Sr				
SELENIUM	Se	0.01	0.01	0.01	0.01
VANADIUM	V				
ZINC	Zn	1.29	1.74	1.72	2.43

LABORATORY DESCRIPTION

OETERMINATION		OATA			
Laboratory Number		3824	3825	3826	3827
Sack Number		103-9	103-10	103-11	103-12
DEPTH	( )	135.0-171.0	172.3-200.5	200.5-204.0	240.0-253.0
PARTICLE SIZE ANALYSIS	(percent)				
Very Coarse Sand	(2.0-1.0 mm)				
Coarse Sand	(1.0-0.5 mm)				
Medium Sand	(0.5-0.25 mm)				
Fine Sand	(0.25-0.10 mm)				
Very Fine Sand	(0.10-0.05 mm)				
TOTAL SAND	(2.0-0.05 mm)	1.8	0.2	1.6	0.3
SILT	(0.05-0.002 mm)	71.1	67.2	80.6	66.3
CLAY	(0.002 mm)	27.1	32.6	17.8	33.4
TEXTURAL CLASS (LAB)		SiCL	SiCL	SiL	SiCL
BULK DENSITY	(g/cm^3)				
HYDRAULIC CONDUCTIVITY	(in/hr)				
6th Hr.		0.06	0.06	0.02	0.02
24th Hr.		0.06	0.08	0.02	0.02
SETTLINC VOLUME	(ml)	34	36	25	41
MOISTURE RETENTION	(percent)				
1/10 bar					
1/3 bar					
15 bar		10.7	11.4	6.7	11.6
SOIL REACTION-pH					
Paste					
1:5 H_2O		8.6	8.5	8.2	8.4
1:2 0.01 M $CaCl_2$		7.7	7.7	7.3	7.6
ORCANIC CARBON	(percent)				
AVAILABLE PHOSPHORUS	(ppm)				
Ca CO_3 EQUIVALENT	(percent)				
CYPSUM REQUIREMENT	(me/100g)	1.6	0.8	0.8	1.2
SATURATION EXTRACT					
Saturation Percentage		49.5	52.3	41.9	54.4
EC_e@ 25°C	(mmhos/cm)	1.12	0.90	1.42	1.22
Ca++	(me/l)	3.46	2.35	4.98	3.71
Mg++	(me/l)	4.68	3.22	5.82	5.22
Na+	(me/l)	1.58	1.66	2.62	1.68
K+	(me/l)	0.06	0.07	0.10	0.07
CO_3-	(me/l)	0.00	0.00	0.00	0.00
HCO_3-	(me/l)	4.29	4.35	3.89	3.02
Cl-	(me/l)	0.04	0.02	0.02	0.02
SO_4-	(me/l)	6.80	4.10	10.00	9.20
NO_3-	(me/l)	0.01	0.00	0.04	0.01
SAR	(me/l)	0.80	1.00	1.10	0.80
Na	(me/100g)	0.10	0.10	0.10	0.10
Ca+Mg	(me/100g)	0.40	0.30	0.40	0.50
1:5 EXTRACT					
EC_5@ 25°C	(mmhos/cm)	0.23	0.21	0.25	0.25
Ca+Mg	(me/l)	1.38	1.24	1.42	1.48
EXCHANCEABLE SODIUM	(percent)	0.90	1.00	0.80	0.70
ACIDITY					
IN KCL exchange acidity					
Total	(me/100g)				
Al+++	(me/100g)				
CATION EXCHANCE CAPACITY	(me/100g)	10.9	11.2	8.6	10.1
NaOAc@pH 8.2					
BORON	(mg/l)				

Table 14
Sheet 1 of 3

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET
DRILL HOLE 81-104

Study Area: Upper Thirteen Mile Creek, Mt
Location. Sec. 8 Twp. 20N Range 53E
2925' N. and 100' E. of SW Corner
Climate:
Land Use:
Relief:
Elevation:
Slope Aspect:
Vegetation:
Erosion:
Stoniness:
Drainage:
Ground Water:
Land Form:
Parent Material:
Soil Series:
Soil Classification:
Profile Description By: L. Parish Date:

DETERMINATION		DATA (mg/1)			
Laboratory Number		20694	20695	20696	20697
Sack Number		104-1	104-2	104-3	104-4
Depth		10.0-32.0	32.0-48.0	48.0-57.0	57.0-67.5
ALUMINUM	Al				
SILVER	Ag				
ARSENIC	As				
BORON	B	0.90	0.60	0.70	1.20
BARIUM	Ba				
BERYLLIUM	Be				
CADMIUM	Cd	0.10	0.04	0.04	0.06
COBALT	Co				
CHROMIUM	Cr				
COPPER	Cu	2.40	2.40	1.40	2.40
IRON	Fe	82.20	35.80	28.80	57.60
MERCURY	Hg	0.12	0.04	0.04	0.08
LITHIUM	Li				
MANGANESE	Mn	4.60	8.80	6.40	15.20
MOLYBDENUM	Mo	0.20	0.10	0.10	0.10
NICKEL	Ni	0.20	0.40	0.20	0.60
PHOSPHOROUS	P				
LEAD	Pb	2.00	2.00	1.40	2.80
STRONTIUM	Sr				
SELENIUM	Se				
VANADIUM	V				
ZINC	Zn	2.00	1.10	1.10	0.90

LABORATORY DESCRIPTION

DETERMINATION		DATA			
Laboratory Number		20694	20695	20696	20697
Sack Number		104-1	104-2	104-3	104-4
DEPTH	(ft)	10.0-32.0	32.0-48.0	48.0-57.0	57.0-67.5
PARTICLE SIZE ANALYSIS	(percent)				
Very Coarse Sand	(2.0-1.0 mm)				
Coarse Sand	(1.0-0.5 mm)				
Medium Sand	(0.5-0.25 mm)	23.0	4.6	21.4	3.7
Fine Sand	(0.25-0.10 mm)				
Very Fine Sand	(0.10-0.05 mm)				
TOTAL SAND	(2.0-0.05 mm)	23.0	4.6	21.4	3.7
SILT	(0.05-0.002 mm)	48.4	72.5	52.1	69.2
CLAY	(0.002 mm)	28.6	23.9	26.5	27.1
TEXTURAL CLASS (LAB)		CL	SiL	SiL	SiCL
BULK DENSITY	(g/cm^3)				
HYDRAULIC CONDUCTIVITY	(in/hr)				
6th Hr.		0.04	0.04	0.04	0.02
24th Hr.		0.04	0.04	0.04	0.04
SETTLING VOLUME	(ml)	26	27	29	35
MOISTURE RETENTION	(percent)				
1/10 bar					
1/3 bar					
15 bar		11.3	8.9	14.1	10.7
SOIL REACTION-pH					
Paste					
1:5 H_2O		7.8	8.4	8.5	8.4
1:2 0.01 M $CaCl_2$					
ORGANIC CARBON	(percent)				
AVAILABLE PHOSPHORUS	(ppm)				
Ca CO_3 EQUIVALENT	(percent)				
GYPSUM REQUIREMENT	(me/100g)	-5.1	-3.2	-3.4	-3.8
SATURATION EXTRACT					
Saturation Percentage		42.44	40.55	39.75	54.43
EC_e@ 25°C	(mmhos/cm)	4.66	3.05	4.29	3.64
Ca^{++}	(me/1)	27.77	13.45	24.98	14.71
Mg^{++}	(me/1)	34.38	19.45	29.31	23.34
Na^+	(me/1)	5.74	4.21	4.45	3.44
K^+	(me/1)	0.83	0.92	1.21	0.93
CO_3^-	(me/1)	0.00	0.00	0.00	0.00
HCO_3^-	(me/1)	3.36	1.16	1.16	1.86
Cl^-	(me/1)	1.35	0.72	0.72	0.35
SO_4^-	(me/1)	57.77	49.39	49.39	35.34
NO_3^-	(me/1)	5.26	10.26	10.26	10.14
SAR	(me/1)	1.03	0.85	0.85	0.79
Na	(me/100g)	0.24	0.18	0.18	0.19
Ca+Mg	(me/100g)	2.64	2.16	2.16	2.07
1:5 EXTRACT					
EC_5 @ 25°C	(mmhos/cm)	1.51	0.53	0.81	0.82
Ca+Mg	(me/1)	7.2	2.0	3.5	3.5
EXCHANGEABLE SODIUM	(percent)	1.41	1.65	1.07	1.10
ACIDITY					
1N KCL exchange acidity					
Total	(me/100g)				
Al^{+++}	(me/100g)				
CATION EXCHANGE CAPACITY	(me/100g)	15.76	12.83	13.70	16.63
NaOAc@pH 8.2					
BORON	(mg/1)				

Table 14
Sheet 2 of 3

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA
SOIL ANALYSIS DATA SHEET

DRILL HOLE 81-104 (cont'd)

Study Area: Upper Thirteen Mile Creek, Mt
Location. Sec. 8 Twp. 20N Range 53E
2925' N. and 100' E. of SW Corner
Climate:
Land Use:
Relief:
Elevation:
Slope Aspect:
Vegetation:
Erosion:
Stoniness:
Drainage:
Cround Water:
Land Form:
Parent Material:
Soil Series:
Soil Classification:
Profile Description By: L. Parish Date:

DETERMINATION		DATA (mg/1)				
Laboratory Number		20698	20699	20700	20701	20702
Sack Number		104-5	104-6	104-7	104-8	104-9
Depth		67.5-73.4	73.4-88.5	88.5-94.5	94.5-100.5	100.5-111.0
ALUMINUM	Al					
SILVER	Ag					
ARSENIC	As					
BORON	B	0.80	0.50	0.60	0.20	0.50
BARIUM	Ba					
BERYLLIUM	Be					
CADMIUM	Cd	0.06	0.04	0.06	0.02	0.04
COBALT	Co					
CHROMIUM	Cr					
COPPER	Cu	2.00	2.20	9.60	2.00	4.60
IRON	Fe	25.00	90.20	206.4	95.80	188.00
MERCURY	Hg	0.03	0.07	0.06	0.06	0.10
LITHIUM	Li					
MANGANESE	Mn	5.40	17.60	21.80	9.20	20.60
MOLYBDENUM	Mo	0.00	0.40	0.60	0.30	0.60
NICKEL	Ni	0.30	1.00	3.80	1.00	1.80
PHOSPHOROUS	P					
LEAD	Pb	1.60	2.00	3.60	2.00	3.20
STRONTIUM	Sr					
SELENIUM	Se					
VANADIUM	V					
ZINC	Zn	1.20	1.40	3.90	2.60	3.60

LABORATORY DESCRIPTION

DETERMINATION		DATA				
Laboratory Number		20698	20699	20700	20701	20702
Sack Number		104-5	104-6	104-7	104-8	104-9
DEPTH	(ft)	67.5-73.4	73.4-88.5	88.5-94.5	94.5-100.5	100.5-110.0
PARTICLE SIZE ANALYSIS	(oercent)					
Very Coarse Sand	(2.0-1.0 mm)					
Coarse Sand	(1.0-0.5 mm)					
Medium Sand	(0.5-0.25 mm)	29.3				
Fine Sand	(0.25-0.10 mm)					
Very Fine Sand	(0.10-0.05 mm)					
TOTAL SAND	(2.0-0.05 mm)	29.3	6.1	1.6	39.8	7.5
SILT	(0.05-0.002 mm)	60.1	70.7	51.6	47.3	55.1
CLAY	(0.002 mm)	10.6	23.2	46.8	12.9	37.4
TEXTURAL CLASS (LAB)		SiL	SiL	SiC	L	SiCL
BULK DENSITY	(g/cm^3)					
HYDRAULIC CONDUCTIVITY	(in/hr)					
6th Hr.		0.11	0.02	0.10	0.13	0.06
24th Hr.		0.17	0.04	0.18	0.18	0.14
SETTLINC VOLUME	(ml)	19	28	37	20	36
MOISTURE RETENTION	(percent)					
1/10 bar						
1/3 bar						
15 bar		7.0	8.8	17.8	6.8	13.2
SOIL REACTION-pH						
Paste						
1:5 H_2O		8.5	8.5	8.3	8.7	8.6
1:2 0.01 M $CaCl_2$						
ORCANIC CARBON	(percent)					
AVAILABLE PHOSPHORUS	(ppm)					
Ca CO_3 EQUIVALENT	(percent)					
GYPSUM REQUIREMENT	(me/100g)	-3.4	-3.3	-4.0	-2.8	-2.7
SATURATION EXTRACT						
Saturation Percentage		28.50	41.75	64.83	33.26	54.79
EC_e@ 25°C	(mmhos/cm)	4.39	3.20	2.37	1.91	1.23
Ca++	(me/1)	27.50	14.60	11.47	9.72	4.89
Mg++	(me/1)	31.75	23.16	14.93	9.86	6.06
Na+	(me/1)	4.07	3.83	2.58	2.49	2.06
K+	(me/1)	0.95	1.14	1.30	1.00	1.04
CO_3-	(me/1)	0.00	0.00	0.00	0.00	0.00
HCO_3-	(me/1)	1.28	2.35	4.95	2.78	4.61
Cl-	(me/1)	0.75	0.60	0.28	0.69	0.23
SO_4-	(me/1)	57.77	37.23	23.98	18.50	8.88
NO_3-	(me/1)	5.41	3.09	0.27	0.24	0.14
SAR	(me/1)	0.75	0.88	0.71	0.79	0.88
Na	(me/100g)	0.12	0.16	0.17	0.08	0.11
Ca+Mg	(me/100g)	1.69	1.58	1.71	0.65	0.60
1:5 EXTRACT						
FC_5@ 25°C	(mmhos/cm)	1.22	0.57	0.59	0.30	0.32
Ca+Mg	(me/1)	6.2	2.2	2.3	1.00	1.0
EXCHANCEABLE SODIUM	(percent)	1.76	1.10	0.56	1.34	0.88
ACIDITY						
IN KCL exchange acidity						
Total	(me/100g)					
Al+++	(me/100g)					
CATION EXCHANGE CAPACITY	(me/100g)	8.37	12.61	27.72	6.30	17.17
NaOAc@pH 8.2						
BORON	(mg/1)					

Table 14
Sheet 3 of 3

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

DRILL HOLE 81-104 (cont'd)

Study Area: Upper Thirteen Mile Creek, Mt
Relief:
Stoniness:
Parent Material:
Location. Sec. 8 Twp. 20N Range 53E
Elevation:
Soil Series:
2925' N. and 100' E. of SW Corner
Slope Aspect:
Drainage:
Soil Classification:
Climate:
Vegetation:
Cround Water:
Land Use:
Erosion:
Land Form:
Profile Description By: L. Pariah Date:

DETERMINATION		DATA (mg/1)				
Laboratory Number		20703	20704	20705	20706	20707
Sack Number		104-10	104-11	104-12	104-13	104-14
Depth		111.0-125.0	125.0-150.8	164.1-174.2	177.9-202.0	211.9-230.0
ALUMINUM	Al					
SILVER	Ag					
ARSENIC	As					
BORON	B	0.60	0.50	0.90	0.40	0.50
BARIUM	Ba					
BERYLLIUM	Be					
CADMIUM	Cd	0.06	0.06	0.12	0.04	0.06
COBALT	Co					
CHROMIUM	Cr					
COPPER	Cu	5.00	7.60	6.80	5.60	6.00
IRON	Fe	157.80	120.60	105.4	142.60	203.80
MEPCURY	Hg	0.09	0.12	0.11	0.08	0.08
LITHIUM	Li					
MANGANESE	Mn	18.20	14.00	15.80	21.80	28.20
MOLYBDENUM	Mo	0.50	0.50	0.50	0.50	0.40
NICKEL	Ni	3.00	4.90	4.00	2.50	1.30
PHOSPHOROUS	P					
LEAD	Pb	4.40	7.80	6.00	3.60	4.20
STRONTIUM	Sr					
SELENIUM	Se					
VANADIUM	V					
ZINC	Zn	4.70	5.20	4.80	2.50	2.60

LABORATORY DESCRIPTION						
DETERMINATION		DATA				
Laboratory Number		20703	20704	20705	20706	20707
Sack Number		104-10	104-11	104-12	104-13	104-14
DEPTH	(ft)	111.0-125.0	125.0-150.8	164.1-174.2	177.9-202.0	211.9-230.0
PARTICLE SIZE ANALYSIS	(percent)					
Very Coarse Sand	(2.0-1.0 mm)					
Coarse Sand	(1.0-0.5 mm)					
Medium Sand	(0.5-0.25 mm)					
Fine Sand	(0.25-0.10 mm)					
Very Fine Sand	(0.10-0.05 mm)					
TOTAL SAND	(2.0-0.05 mm)	1.9	1.1	2.5	2.6	0.8
SILT	(0.05-0.002 mm)	60.3	57.3	61.2	74.2	65.6
CLAY	(0.002 mm)	37.8	41.6	36.3	23.2	33.6
TEXTURAL CLASS (LAB)		SiCL	SiC	SiCL	SiL	SiCL
BULK DENSITY	(g/cm^3)					
HYDRAULIC CONDUCTIVITY	(in/hr)					
6th Hr.		0.06	0.00	0.00	0.00	0.00
24th Hr.		0.10	0.02	0.00	0.00	0.00
SETTLING VOLUME	(ml)	39	43	36	37	72
MOISTURE RETENTION	(percent)					
1/10 bar						
1/3 bar						
15 bar		14.3	17.1	17.8	9.7	13.8
SOIL REACTION-pH						
Paste						
1:5 H_2O		8.6	8.7	8.9	9.1	9.4
1:2 0.01 M $CaCl_2$						
ORCANIC CARBON	(percent)					
AVAILABLE PHOSPHORUS	(ppm)					
Ca CO_3 EQUIVALENT	(percent)					
GYPSUM REQUIREMENT	(me/100g)	-2.1	-2.3	0.8	-1.3	-0.4
SATURATION EXTRACT						
Saturation Percentage		52.87	63.71	58.88	70.03	60.80
EC$_e$@ 25°C	(mmhos/cm)	1.13	1.24	1.53	1.78	1.81
Ca++	(me/1)	4.39	3.35	3.02	2.31	0.93
Mg++	(me/1)	5.52	4.61	4.25	3.08	1.00
Na+	(me/1)	1.87	5.55	8.51	13.06	16.79
K+	(me/1)	1.01	0.86	0.82	0.76	0.55
CO_3-	(me/1)	0.00	0.00	0.00	0.00	0.23
HCO_3-	(me/1)	4.03	4.15	4.77	5.31	8.06
Cl-	(me/1)	0.25	0.48	0.62	0.60	0.28
SO_4-	(me/1)	8.21	8.45	10.86	12.40	9.70
NO_3-	(me/1)	0.11	0.10	0.11	0.08	0.08
SAR	(me/1)	0.84	2.78	4.46	7.96	17.10
Na	(me/100g)	0.10	0.35	0.50	0.91	1.02
Ca+Mg	(me/100g)	0.52	0.51	0.43	0.38	0.12
1:5 EXTRACT						
FC$_5$@ 25°C	(mmhos/cm)	0.30	0.32	0.36	0.36	0.43
Ca+Mg	(me/1)	0.9	0.70	0.60	0.3	0.4
EXCHANGEABLE SODIUM	(percent)	1.04	2.41	4.55	5.95	14.75
ACIDITY						
IN KCL exchange acidity						
Total	(me/100g)					
Al+++	(me/100g)					
CATION EXCHANGE CAPACITY	(me/100g)	15.87	21.09	27.61	17.39	79.02
NaOAc@pH 8.2						
BORON	(mg/I)					

Table 15
Sheet 1 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

DRILL HOLE 81-105

Study Area: Upper Thirteen Mile Creek, Mt
Location. Sec. 32 Twp. 21N Range 53E
790' W. and 125' S. of NE Corner
Climate:
Land Use:
Relief:
Elevation:
Slope Aspect:
Vegetation:
Erosion:
Stoniness:
Drainage:
Cround Water:
Land Form:
Parent Material:
Soil Series:
Soil Classification:
Profile Description By: L. Parish Date:

DETERMINATION		DATA (mg/l)			
Laboratory Number		20708	20709	20710	20711
Sack Number		105-1	105-2	105-3	105-4
Depth		10.0-14.0	14.0-24.0	24.0-44.0	44.0-49.3
ALUMINUM	Al				
SILVER	Ag				
ARSENIC	As				
BORON	B	0.30	0.30	0.30	0.30
BARIUM	Ba				
BERYLLIUM	Be				
CADMIUM	Cd	0.02	0.06	0.04	0.06
COBALT	Co				
CHROMIUM	Cr				
COPPER	Cu	0.80	0.60	1.20	4.20
IRON	Fe	30.80	26.20	29.40	65.40
MEPCURY	Hg	0.05	0.06	0.04	0.12
LITHIUM	Li				
MANGANESE	Mn	10.80	1.40	11.80	8.60
MOLYBDENUM	Mo	0.20	0.20	0.10	0.50
NICKEL	Ni	0.20	0.10	0.20	0.80
PHOSPHOROUS	P				
LEAD	Pb	1.40	1.80	1.40	6.20
STRONTIUM	Sr				
SELENIUM	Se				
VANADIUM	V				
ZINC	Zn	1.60	0.90	0.50	1.60

LABORATORY DESCRIPTION					
DETERMINATION		DATA			
Laboratory Number		20708	20709	20710	20711
Sack Number		105-1	105-2	105-3	105-4
DEPTH	(ft)	10.0-14.0	14.0-24.0	24.0-44.0	44.0-49.3
PARTICLE SIZE ANALYSIS	(percent)				
Very Coarse Sand	(2.0-1.0 mm)				
Coarse Sand	(1.0-0.5 mm)				
Medium Sand	(0.5-0.25 mm)				
Fine Sand	(0.25-0.10 mm)				
Very Fine Sand	(0.10-0.05 mm)				
TOTAL SAND	(2.0-0.05 mm)	35.0	9.8	5.4	2.5
SILT	(0.05-0.002 mm)	56.2	63.8	70.2	72.1
CLAY	(0.002 mm)	8.8	26.4	24.4	25.4
TEXTURAL CLASS (LAB)		SiL	SiL	SiL	SiL
BULK DENSITY	(g/cm^3)				
HYDRAULIC CONDUCTIVITY	(in/hr)				
6th Hr.		0.08	0.02	0.02	0.02
24th Hr.		0.10	0.02	0.02	0.02
SETTLINC VOLUME	(ml)	19	27	32	30
MOISTURE RETENTION	(percent)				
1/10 bar					
1/3 bar					
15 bar		5.6	15.1	15.6	15.3
SOIL REACTION-pH					
Paste					
1:5 H_2O		8.9	8.2	8.5	8.7
1:2 0.01 M $CaCl_2$					
ORCANIC CARBON	(percent)				
AVAILABLE PHOSPHORUS	(ppm)				
Ca CO_3 EQUIVALENT	(percent)				
CYPSUM REQUIREMENT	(me/100g)	-3.9	-6.7	-5.8	-4.2
SATURATION EXTRACT					
Saturation Percentage		36.56	58.75	55.48	57.97
EC_e@ 25°C	(mmhos/cm)	4.78	4.35	3.66	1.91
Ca++	(me/l)	14.99	25.85	25.47	8.84
Mg++	(me/l)	43.15	34.01	23.97	10.22
Na+	(me/l)	11.57	4.93	3.59	3.06
K+	(me/l)	0.55	0.81	0.73	0.86
CO_3-	(me/l)	0.00	0.00	0.00	0.00
HCO_3-	(me/l)	1.52	1.59	1.16	2.57
Cl-	(me/l)	3.87	0.57	0.50	0.50
SO_4-	(me/l)	65.87	63.71	51.01	19.39
NO_3-	(me/l)	0.19	0.86	0.62	0.12
SAR	(me/l)	2.15	0.90	0.72	0.99
Na	(me/100g)	0.42	0.29	0.20	0.18
Ca+Mg	(me/100g)	2.13	3.52	2.74	1.10
1:5 EXTRACT					
FC_5@ 25°C	(mmhos/cm)	0.65	2.10	0.92	0.40
Ca+Mg	(me/l)	2.5	10.4	4.4	1.3
EXCHANCEABLE SODIUM	(percent)	2.11	0.86	1.13	1.51
ACIDITY					
IN KCL exchange acidity					
Total	(me/100g)				
Al+++	(me/100g)				
CATION EXCHANCE CAPACITY	(me/100g)	8.26	20.65	10.98	14.35
NaOAc@pH 8.2					
BORON	(mg/l)				

Table 15
Sheet 2 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET
DRILL HOLE 81-105 (cont'd)

Study Area: Upper Thirteen Mile Creek, Mt
Location. Sec. 32 Twp. 21N Range 53E
790' W. and 125' S. of NE Corner
Climate:
Land Use:
Relief:
Elevation:
Slope Aspect:
Vegetation:
Erosion:
Stoniness:
Drainage:
Ground Water:
Land Form:
Parent Material:
Soil Series:
Soil Classification:
Profile Description By: L. Parish Date:

DETERMINATION		DATA (mg/1)			
Laboratory Number		20712	02713	20714	20715
Sack Number		105-5	105-6	105-7	105-8
Depth		51.0-71.0	71.0-94.0	94.0-101.9	134.0-141.0
ALUMINUM	Al				
SILVER	Ag				
ARSENIC	As				
BORON	B	0.30	0.40	0.00	0.90
BARIUM	Ba				
BERYLLIUM	Be				
CADMIUM	Cd	0.04	0.04	0.06	0.06
COBALT	Co				
CHROMIUM	Cr				
COPPER	Cu	4.20	4.20	5.20	3.40
IRON	Fe	136.00	146.60	80.60	32.40
MERCURY	Hg	0.07	0.07	0.07	0.03
LITHIUM	Li				
MANGANESE	Mn	21.00	23.20	8.80	3.00
MOLYBDENUM	Mo	0.40	0.40	0.90	0.30
NICKEL	Ni	1.80	1.90	3.80	1.80
PHOSPHOROUS	P				
LEAD	Pb	3.20	3.40	7.00	8.0
STRONTIUM	Sr				
SELENIUM	Se				
VANADIUM	V				
ZINC	Zn	2.50	3.30	5.20	4.50

LABORATORY DESCRIPTION

DETERMINATION		DATA			
Laboratory Number		20712	20713	20714	20715
Sack Number		105-5	105-6	105-7	105-8
DEPTH	(ft)	51.0-71.0	71.0-94.0	94.0-101.9	134.0-141.0
PARTICLE SIZE ANALYSIS	(percent)				
Very Coarse Sand	(2.0-1.0 mm)				
Coarse Sand	(1.0-0.5 mm)				
Medium Sand	(0.5-0.25 mm)				
Fine Sand	(0.25-0.10 mm)				
Very Fine Sand	(0.10-0.05 mm)				
TOTAL SAND	(2.0-0.05 mm)	2.4	2.2	1.5	17.8
SILT	(0.05-0.002 mm)	70.8	70.0	59.8	61.2
CLAY	(0.002 mm)	26.8	27.8	38.7	21.0
TEXTURAL CLASS (LAB)		SiL	SiCL	SiCL	SiL
BULK DENSITY	(g/cm^3)				
HYDRAULIC CONDUCTIVITY	(in/hr)				
6th Hr.		0.02	0.04	0.02	0.02
24th Hr.		0.04	0.06	0.06	0.04
SETTLING VOLUME	(ml)	32	34	56	26
MOISTURE RETENTION	(percent)				
1/10 bar					
1/3 bar					
15 bar		19.5	16.4	20.7	13.4
SOIL REACTION-pH					
Paste					
1:5 H_2O		8.7	8.7	8.7	8.7
1:2 0.01 M $CaCl_2$					
ORGANIC CARBON	(percent)				
AVAILABLE PHOSPHORUS	(ppm)				
Ca CO_3 EQUIVALENT	(percent)				
GYPSUM REQUIREMENT	(me/100g)	-3.1	-1.2	-2.4	-1.3
SATURATION EXTRACT					
Saturation Percentage		54.97	52.49	64.60	48.58
EC_e@ 25°C	(mmhos/cm)	2.02	1.19	0.76	0.69
Ca++	(me/1)	10.10	6.04	3.79	2.80
Mg++	(me/1)	11.40	5.43	2.71	3.71
Na+	(me/1)	2.25	1.20	0.77	1.00
K+	(me/1)	0.95	0.78	0.71	0.48
CO_3-	(me/1)	0.00	0.00	0.00	0.00
HCO_3-	(me/1)	2.93	3.41	3.23	3.05
Cl-	(me/1)	0.51	0.32	0.22	0.40
SO_4-	(me/1)	21.01	9.42	4.70	3.88
NO_3-	(me/1)	0.08	0.90	0.09	0.11
SAR	(me/1)	0.69	0.50	0.42	0.56
Na	(me/100g)	0.12	0.06	0.05	0.05
Ca+Mg	(me/100g)	1.18	0.60	0.42	0.32
1:5 EXTRACT					
FC_5@ 25°C	(mmhos/cm)	0.40	0.26	0.22	0.15
Ca+Mg	(me/1)	1.50	0.90	0.70	0.50
EXCHANGEABLE SODIUM	(percent)	1.48	0.71	0.73	0.60
ACIDITY					
IN KCL exchange acidity					
Total	(me/100g)				
Al+++	(me/100g)				
CATION EXCHANGE CAPACITY	(me/100g)	7.83	11.30	14.57	11.74
NaOAc@pH B.2					
BORON	(mg/1)				

Table 16

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

DRILL HOLE 81-106

Study Area: Southwest Clendive, Mt
Relief:
Stoniness:
Parent Material:
Location. Sec. 14 Twp. 15N Range 53E
Elevation:
Soil Series:
3' N. and 20' W. of SE Corner
Slope Aspect:
Drainage:
Soil Classification:
Climate:
Vegetation:
Ground Water:
Land Use:
Erosion:
Land Form:
Profile Description By: C. Botdorf Date:

DETERMINATION		DATA (mg/l)					
Laboratory Number		20716	20717	20718	20719	20720	20721
Sack Number		106-1	106-2	106-3	106-4	106-5	106-6
Depth		10.0-25.0	33.0-57.0	57.0-78.0	78.0-99.0	118.0-130.0	130.0-140.0
ALUMINUM	Al						
SILVER	Ag						
ARSENIC	As						
BORON	B	0.40	0.30	0.30	0.70	0.70	0.70
BARIUM	Ba						
BERYLLIUM	Be						
CADMIUM	Cd	0.02	0.02	0.02	0.04	0.08	0.08
COBALT	Co						
CHROMIUM	Cr						
COPPER	Cu	5.20	0.80	0.80	3.00	3.20	4.00
IRON	Fe	124.60	25.60	62.00	128.60	76.60	160.80
MERCURY	Hg	0.05	0.02	0.02	0.07	0.06	0.03
LITHIUM	Li						
MANGANESE	Mn	61.2	6.40	19.60	15.80	7.20	19.0
MOLYBDENUM	Mo	1.00	0.20	0.20	0.40	0.50	0.40
NICKEL	Ni	1.50	0.10	0.30	1.90	2.90	3.40
PHOSPHOROUS	P						
LEAD	Pb	13.60	1.40	1.40	4.20	4.80	3.40
STRONTIUM	Sr						
SELENIUM	Se						
VANADIUM	V						
ZINC	Zn	22.00	1.70	2.0	3.3	3.80	3.70

LABORATORY DESCRIPTION

DETERMINATION		DATA					
Laboratory Number		20716	20717	20718	20719	20720	20721
Sack Number		106-1	106-2	106-3	106-4	106-5	106-6
DEPTH	(ft)	10.0-25.0	33.0-57.0	57.0-78.0	78.0-99.0	118.0-130.0	130.0-140.0
PARTICLE SIZE ANALYSIS	(percent)						
Very Coarse Sand	(2.0-1.0 mm)	12.4		12.2			
Coarse Sand	(1.0-0.5 mm)	16.2		4.3			
Medium Sand	(0.5-0.25 mm)	22.8	9.4	2.0	7.4		
Fine Sand	(0.25-0.10 mm)	25.2		26.0			
Very Fine Sand	(0.10-0.05 mm)	6.6		28.1			
TOTAL SAND	(2.0-0.05 mm)	83.2	9.4	72.6	7.4	2.8	2.8
SILT	(0.05-0.002 mm)	13.0	66.7	22.8	72.9	76.2	74.9
CLAY	(0.002 mm)	3.8	23.9	4.6	19.7	21.0	22.3
TEXTURAL CLASS (LAB)		LCOS	SiL	FSL	SiL	SiL	SiL
BULK DENSITY	(g/cm^3)						
HYDRAULIC CONDUCTIVITY	(in/hr)						
6th Hr.		0.26	0.02	0.39	0.02	0.00	0.00
24th Hr.		0.47	0.04	0.59	0.02	0.00	0.00
SETTLING VOLUME	(ml)	16	22	17	34	52	56
MOISTURE RETENTION	(percent)						
1/10 bar							
1/3 bar							
15 bar		4.4	15.7	5.0	13.2	16.4	17.3
SOIL REACTION-pH							
Paste							
1:5 H_2O		9.5	9.1	9.2	9.3	9.7	9.7
1:2 0.01 M $CaCl_2$							
ORGANIC CARBON	(percent)						
AVAILABLE PHOSPHORUS	(ppm)						
Ca CO_3 EQUIVALENT	(percent)						
GYPSUM REQUIREMENT	(me/100g)	-2.7	-1.9	-1.3	-1.1	1.9	2.4
SATURATION EXTRACT							
Saturation Percentage		21.70	49.17	25.34	46.72	52.37	52.79
EC_e@ 25°C	(mmhos/cm)	1.00	0.42	0.78	1.41	1.15	1.13
Ca++	(me/l)	1.15	1.26	2.20	1.10	0.49	0.49
Mg++	(me/l)	2.71	2.53	3.35	1.81	0.36	0.36
Na+	(me/l)	6.00	0.77	2.49	7.99	11.77	11.48
K+	(me/l)	0.31	0.20	0.28	0.46	0.25	0.24
CO_3-	(me/l)	0.00	0.00	0.00	0.00	0.12	0.00
HCO_3-	(me/l)	4.25	2.49	2.63	5.01	6.44	8.44
Cl-	(me/l)	1.21	0.87	1.82	0.41	0.28	0.25
SO_4-	(me/l)	4.97	1.64	3.48	4.97	4.91	3.34
NO_3-	(me/l)	0.00	0.61	0.38	0.01	0.01	0.01
SAR	(me/l)	4.75	0.56	1.49	6.62	17.99	17.55
Na	(me/100g)	0.14	0.04	0.06	0.37	0.62	0.61
Ca+Mg	(me/100g)	0.08	0.19	0.14	0.14	0.04	0.05
1:5 EXTRACT							
EC_5@ 25°C	(mmhos/cm)	0.13	0.15	0.12	0.21	0.31	0.33
Ca+Mg	(me/l)	0.30	0.50	0.40	0.30	0.50	0.50
EXCHANGEABLE SODIUM	(percent)	8.26	0.92	2.43	3.91	17.66	20.29
ACIDITY							
IN KCL exchange acidity							
Total	(me/100g)						
Al+++	(me/100g)						
CATION EXCHANGE CAPACITY	(me/100g)	4.78	19.24	5.76	8.80	12.83	13.04
NaOAc@pH 8.2							
BORON	(mg/l)						

Table 17

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET
GEOLOGIC DRILL HOLE 81-107

Study Area: Southwest Glendive, Montana
Relief:
Stoniness:
Parent Material:
Location. Sec. 26 Twp. 15N. Range 53E.
75' S. and 1990' W. of SE Corner
Elevation:
Soil Series:
Slope Aspect:
Drainage:
Soil Classification:
Climate:
Vegetation:
Cround Water:
Land Use:
Erosion:
Land Form:
Profile Description By: L. Parish Date:

DETERMINATION		DATA (mg/1)		
Laboratory Number		20,780	20,781	20,782
Sack Number				
Depth		10.0-15.0	94.0-118.7	134.1-144.2
ALUMINUM	Al			
SILVER	Ag			
ARSENIC	As			
BORON	B	0.00	0.00	0.48
BARIUM	Ba			
BERYLLIUM	Be			
CADMIUM	Cd	0.02	0.08	0.16
COBALT	Co			
CHROMIUM	Cr			
COPPER	Cu	0.18	10.40	12.00
IRON	Fe	71.20	147.80	214.20
MEPCURY	Hg	0.031	0.062	0.062
LITHIUM	Li			
MANCANESE	Mn	36.20	57.80	25.00
MOLYBDENUM	Mo	0.22	0.45	0.64
NICKEL	Ni	0.60	2.40	4.30
PHOSPHOROUS	P			
LEAD	Pb	1.60	7.40	7.40
STRONTIUM	Sr			
SELENIUM	Se	<0.1	<0.1	<0.1
VANADIUM	V			
ZINC	Zn	2.44	6.64	6.42

LABORATORY DESCRIPTION

DETERMINATION		DATA		
Laboratory Number		20,780	20,781	20,782
Sack Number				
DEPTH	(ft)	10.0-15.0	94.0-118.7	134.1-144.2
PARTICLE SIZE ANALYSIS	(oercent)			
Very Coarse Sand	(2.0-1.0 mm)	4.2		
Coarse Sand	(1.0-0.5 mm)	21.6		
Medium Sand	(0.5-0.25 mm)	17.6		
Fine Sand	(0.25-0.10 mm)	22.1		
Very Fine Sand	(0.10-0.05 mm)	9.4		
TOTAL SAND	(2.0-0.05 mm)	74.9	3.0	2.4
SILT	(0.05-0.002 mm)	19.8	60.3	58.8
CLAY	(0.002 mm)	5.3	36.7	38.8
TEXTURAL CLASS (LAB)		CoSL	SiCL	SiCL
BULK DENSITY	(g/cm^3)			
HYDRAULIC CONDUCTIVITY	(in/hr)			
6th Hr.		0.09	0.00	0.00
24th Hr.		0.09	0.04	0.00
SETTLINC VOLUME	(ml)	15.0	35.0	32.0
MOISTURE RETENTION	(percent)			
1/10 bar				
1/3 bar				
15 bar		3.6	16.9	16.3
SOIL REACTION-pH				
Paste				
1:5 H_2O		9.4	8.8	8.9
1:2 0.01 M $CaCl_2$				
ORCANIC CARBON	(percent)			
AVAILABLE PHOSPHORUS	(ppm)			
Ca CO_3 EQUIVALENT	(percent)			
CYPSUM REQUIREMENT	(me/100g)	+0.59	+0.27	+0.68
SATURATION EXTRACT				
Saturation Percentage		20.3	52.0	55.0
EC_e@ 25°C	(mmhos/cm)	1.03	0.83	1.40
Ca++	(me/1)	0.99	2.96	2.25
Mg++	(me/1)	2.08	3.89	2.35
Na+	(me/1)	8.32	1.82	10.81
K+	(me/1)	0.45	0.65	0.74
CO_3-	(me/1)	0.00	0.00	0.09
HCO_3-	(me/1)	4.28	3.64	7.07
Cl-	(me/1)	1.24	0.17	0.18
SO_4-	(me/1)	5.04	5.41	8.12
NO_3-	(me/1)	0.53	0.15	0.30
SAR	(me/1)	6.70	0.98	7.10
Na	(me/100g)	0.17	0.09	0.59
Ca+Mg	(me/100g)	0.06	0.36	0.25
1:5 EXTRACT				
FC_5@ 25°C	(mmhos/cm)	0.15	0.20	0.33
Ca+Mg	(me/1)	0.69	1.36	0.86
EXCHANCEABLE SODIUM	(percent)	6.75	0.36	5.95
ACIDITY				
IN KCL exchange acidity				
Total	(me/100g)			
Al+++	(me/100g)			
CATION EXCHANCE CAPACITY	(me/100g)	7.07	13.48	19.78
NaOAc@pH 8.2				
BORON	(mg/1)			

Table 18
Sheet 1 of 3

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET

GEOLOGIC DRILL HOLE 81-108

Study Area: Circle 2, Montana
Location. Sec. 26 Twp. 20N Range 49E
790' S. and 1580' E. of NW Corner
Climate:
Land Use:
Relief:
Elevation:
Slope Aspect:
Vegetation:
Erosion:
Stoniness:
Drainage:
Ground Water:
Land Form:
Parent Material:
Soil Series:
Soil Classification:
Profile Description By: L. Parish Date:

DETERMINATION		DATA (mg/l)				
Laboratory Number Sack Number		20,783	20,784	20,785	20,786	20,787
Depth		15.0-23.1	23.1-46.6	47.2-68.0	68.0-72.5	76.8-90.0
ALUMINUM	Al					
SILVER	Ag					
ARSENIC	As					
BORON	B	1.88	0.63	0.00	0.86	0.00
BARIUM	Ba					
BERYLLIUM	Be					
CADMIUM	Cd	0.10	0.04	0.06	0.08	0.10
COBALT	Co					
CHROMIUM	Cr					
COPPER	Cu	3.40	3.40	5.80	12.00	5.00
IRON	Fe	90.80	50.20	138.00	203.60	225.20
MERCURY	Hg	0.037	0.053	0.044	0.047	0.034
LITHIUM	Li					
MANGANESE	Mn	95.20	34.20	28.40	34.60	25.80
MOLYBDENUM	Mo	0.07	0.07	0.07	0.36	0.36
NICKEL	Ni	1.70	0.60	1.40	2.60	2.80
PHOSPHOROUS	P					
LEAD	Pb	3.80	2.60	3.40	7.00	3.80
STRONTIUM	Sr					
SELENIUM	Se	<0.1	<0.1	<0.1	<0.1	<0.1
VANADIUM	V					
ZINC	Zn	1.78	1.36	2.24	4.32	4.84

LABORATORY DESCRIPTION

DETERMINATION		DATA				
Laboratory Number		20,783	20,784	20,785	20,786	20,787
Sack Number						
DEPTH	(ft)	15.0-23.1	23.1-46.6	47.2-68.0	68.0-72.5	76.8-90.0
PARTICLE SIZE ANALYSIS	(percent)					
Very Coarse Sand	(2.0-1.0 mm)					
Coarse Sand	(1.0-0.5 mm)					
Medium Sand	(0.5-0.25 mm)					
Fine Sand	(0.25-0.10 mm)					
Very Fine Sand	(0.10-0.05 mm)					
TOTAL SAND	(2.0-0.05 mm)	3.7	11.1	1.7	5.5	8.9
SILT	(0.05-0.002 mm)	67.1	61.1	70.3	58.6	78.0
CLAY	(0.002 mm)	29.2	27.8	28.0	35.9	13.1
TEXTURAL CLASS (LAB)		SiCL	SiCL	SiCL	SiCL	SiL
BULK DENSITY	(g/cm^3)					
HYDRAULIC CONDUCTIVITY	(in/hr)					
6th Hr.		0.04	0.00	0.00	0.00	0.00
24th Hr.		0.04	0.00	0.00	0.00	0.00
SETTLING VOLUME	(ml)	27.0	30.0	31.0	44.0	33.0
MOISTURE RETENTION	(percent)					
1/10 bar						
1/3 bar						
15 bar		14.5	10.4	13.1	20.7	16.3
SOIL REACTION-pH						
Paste						
1:5 H_2O		8.3	8.8	8.8	8.9	9.3
1:2 0.01 M $CaCl_2$						
ORGANIC CARBON	(percent)					
AVAILABLE PHOSPHORUS	(ppm)					
Ca CO_3 EQUIVALENT	(percent)					
GYPSUM REQUIREMENT	(me/100g)	-2.88	-0.08	+1.20	+1.10	+0.61
SATURATION EXTRACT						
Saturation Percentage		50.1	51.1	50.0	58.0	44.5
EC_e @ 25°C	(mmhos/cm)	6.70	5.00	5.00	4.00	4.00
Ca++	(me/l)	37.05	19.98	14.38	6.20	3.84
Mg++	(me/l)	42.79	24.88	16.46	9.68	4.25
Na+	(me/l)	12.77	22.14	36.49	34.39	40.32
K+	(me/l)	0.97	0.97	1.13	1.17	0.89
CO_3-	(me/l)	0.00	0.00	0.00	0.00	0.00
HCO_3-	(me/l)	1.30	1.36	2.10	4.64	5.00
Cl-	(me/l)	1.75	0.88	0.66	0.55	0.56
SO_4-	(me/l)	54.13	43.72	62.46	46.85	46.85
NO_3-	(me/l)	37.70	23.81	5.03	1.61	0.13
SAR	(me/l)	2.00	4.70	9.30	12.00	20.00
Na	(me/100g)	0.64	1.13	1.82	1.99	1.79
Ca+Mg	(me/100g)	4.00	2.29	1.54	0.92	0.36
1:5 EXTRACT						
EC_5 @ 25°C	(mmhos/cm)	1.82	0.90	1.00	0.70	0.57
Ca+Mg	(me/l)	19.03	5.87	5.07	1.41	0.65
EXCHANGEABLE SODIUM	(percent)	1.49	2.90	9.38	9.96	14.17
ACIDITY						
1N KCL exchange acidity						
Total	(me/100g)					
Al+++	(me/100g)					
CATION EXCHANGE CAPACITY	(me/100g)	18.91	15.00	11.52	13.59	9.78
NaOAc@pH 8.2						
BORON	(mg/l)					

Table 18
Sheet 2 of 3

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET
GEOLOGIC DRILL HOLE 81-108 (cont'd)

Study Area: Circle 2, Montana
Location. Sec. 26 Twp. 20N Range 49E
790' S. and 1580' E. of NW Corner
Climate:
Land Use:
Relief:
Elevation:
Slope Aspect:
Vegetation:
Erosion:
Stoniness:
Drainage:
Ground Water:
Land Form:
Parent Material:
Soil Series:
Soil Classification:
Profile Description By: L. Parish Date:

DETERMINATION		DATA (mg/l)				
Laboratory Number		20,788	20,789	20,790	20,791	20,792
Sack Number						
Depth		90.0-106.8	110.4-123.0	123.0-147.4	149.7-162.8	165.0-179.0
ALUMINUM	Al					
SILVER	Ag					
ARSENIC	As					
BORON	B	0.39	1.13	0.29	0.59	0.07
BARIUM	Ba					
BERYLLIUM	Be					
CADMIUM	Cd	0.06	0.10	0.06	0.08	0.06
COBALT	Co					
CHROMIUM	Cr					
COPPER	Cu	8.20	14.00	9.20	8.60	5.20
IRON	Fe	299.00	243.40	327.00	227.00	204.60
MERCURY	Hg	0.044	0.056	0.056	0.044	0.041
LITHIUM	Li					
MANGANESE	Mn	36.80	25.20	33.00	23.80	24.80
MOLYBDENUM	Mo	0.41	0.45	0.37	0.34	0.15
NICKEL	Ni	1.90	2.40	1.80	1.90	1.70
PHOSPHOROUS	P					
LEAD	Pb	3.60	8.20	3.80	7.60	3.60
STRONTIUM	Sr					
SELENIUM	Se	<0.1	<0.1	<0.1	<0.1	<0.1
VANADIUM	V					
ZINC	Zn	3.96	4.56	4.52	3.90	4.08

LABORATORY DESCRIPTION

DETERMINATION		DATA				
Laboratory Number		20,788	20,789	20,790	20,791	20,792
Sack Number						
DEPTH	(ft)	90.0-106.8	110.4-123.0	123.0-147.4	149.7-162.8	164.0-179.0
PARTICLE SIZE ANALYSIS	(percent)					
Very Coarse Sand	(2.0-1.0 mm)					
Coarse Sand	(1.0-0.5 mm)					
Medium Sand	(0.5-0.25 mm)					
Fine Sand	(0.25-0.10 mm)					
Very Fine Sand	(0.10-0.05 mm)					
TOTAL SAND	(2.0-0.05 mm)	13.0	6.1	0.3		6.6
SILT	(0.05-0.002 mm)	57.6	63.0	68.1		79.1
CLAY	(0.002 mm)	29.4	30.9	31.6		14.3
TEXTURAL CLASS (LAB)		SiCL	SiCL	SiCL		SiL
BULK DENSITY	(g/cm^3)					
HYDRAULIC CONDUCTIVITY	(in/hr)					
6th Hr.		0.00	0.00	0.00	0.00	0.00
24th Hr.		0.00	0.00	0.00	0.00	0.00
SETTLING VOLUME	(ml)	76.0	90.0	104.0	98.0	66.0
MOISTURE RETENTION	(percent)					
1/10 bar						
1/3 bar						
15 bar		11.0	21.1	18.3	20.3	11.6
SOIL REACTION-pH						
Paste						
1:5 H_2O		9.6	9.7	9.8	9.8	9.9
1:2 0.01 M $CaCl_2$						
ORGANIC CARBON	(percent)					
AVAILABLE PHOSPHORUS	(ppm)					
Ca CO_3 EQUIVALENT	(percent)					
GYPSUM REQUIREMENT	(me/100g)	+2.40	+5.0	+5.6	+4.8	+0.16
SATURATION EXTRACT						
Saturation Percentage		49.5	53.2	58.5	48.0	39.0
EC_e@ 25°C	(mmhos/cm)	2.80	2.30	2.10	2.52	2.25
Ca++	(me/l)	1.26	0.55	0.44	0.49	0.33
Mg++	(me/l)	1.35	0.54	0.27	0.54	0.27
Na+	(me/l)	29.03	26.45	24.10	28.98	24.15
K+	(me/l)	0.65	0.36	0.29	0.31	0.25
CO_3-	(me/l)	0.00	0.30	0.40	0.12	0.18
HCO_3-	(me/l)	6.65	10.20	9.48	9.73	8.63
Cl-	(me/l)	0.42	0.44	0.21	0.28	0.22
SO_4-	(me/l)	26.44	15.62	13.43	19.15	15.62
NO_3-	(me/l)	0.16	0.16	0.13	0.15	0.01
SAR	(me/l)	25.00	36.0	40.0	40.0	44.0
Na	(me/100g)	1.44	1.41	1.41	1.39	0.95
Ca+Mg	(me/100g)	0.13	0.06	0.04	0.05	0.02
1:5 EXTRACT						
EC_5@ 25°C	(mmhos/cm)	0.51	0.53	0.58	0.54	0.44
Ca+Mg	(me/l)	1.19	1.15	1.31	1.23	0.94
EXCHANGEABLE SODIUM	(percent)	24.58	32.76	38.79	44.06	37.79
ACIDITY						
1N KCL exchange acidity						
Total	(me/100g)					
Al+++	(me/100g)					
CATION EXCHANGE CAPACITY	(me/100g)	8.26	13.26	12.61	10.33	6.85
NaOAc@pH 8.2						
BORON	(mg/l)					

Table 18
Sheet 3 of 3

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET
GEOLOGIC DRILL HOLE 81-108 (cont'd)

Study Area: Circle 2, Montana
Location. Sec. 26 Twp. 20N. Range 49E.
790' S. and 1580' E. of NW Corner
Climate:
Land Use:
Relief:
Elevation:
Slope Aspect:
Vegetation:
Erosion:
Stoniness:
Drainage:
Ground Water:
Land Form:
Parent Material:
Soil Series:
Soil Classification:
Profile Description By: L. Parish Date:

DETERMINATION		DATA (mg/1)		
Laboratory Number		20,793	20,794	20,795
Sack Number				
Depth		179.0-194.0	194.0-206.4	224.8-242.0
ALUMINUM	Al			
SILVER	Ag			
ARSENIC	As			
BORON	B	0.48	0.75	0.75
BARIUM	Ba			
BERYLLIUM	Be			
CADMIUM	Cd	0.06	0.08	0.06
COBALT	Co			
CHROMIUM	Cr			
COPPER	Cu	7.80	9.60	9.00
IRON	Fe	262.00	267.80	276.40
MERCURY	Hg	0.053	0.053	0.066
LITHIUM	Li			
MANGANESE	Mn	33.40	35.60	25.20
MOLYBDENUM	Mo	0.31	0.56	0.39
NICKEL	Ni	1.70	3.20	2.40
PHOSPHOROUS	P			
LEAD	Pb	3.20	5.00	7.60
STRONTIUM	Sr			
SELENIUM	Se	<0.1	<0.1	<0.1
VANADIUM	V			
ZINC	Zn	3.38	6.14	3.82

LABORATORY DESCRIPTION				
DETERMINATION		DATA		
Laboratory Number		20,793	20,794	20,795
Sack Number				
DEPTH	(ft)	179.0-194.0	194.0-206.4	224.8-242.0
PARTICLE SIZE ANALYSIS	(percent)			
Very Coarse Sand	(2.0-1.0 mm)			
Coarse Sand	(1.0-0.5 mm)			
Medium Sand	(0.5-0.25 mm)			
Fine Sand	(0.25-0.10 mm)			
Very Fine Sand	(0.10-0.05 mm)			
TOTAL SAND	(2.0-0.05 mm)	3.4	1.8	1.6
SILT	(0.05-0.002 mm)	73.9	64.8	66.2
CLAY	(0.002 mm)	22.7	33.4	33.2
TEXTURAL CLASS (LAB)		SiL	SiCL	SiCL
BULK DENSITY	(g/cm^3)			
HYDRAULIC CONDUCTIVITY	(in/hr)			
6th Hr.		0.00	0.00	0.00
24th Hr.		0.00	0.00	0.00
SETTLING VOLUME	(ml)	78.0	48.0	144.0
MOISTURE RETENTION	(percent)			
1/10 bar				
1/3 bar				
15 bar		13.2	15.4	16.0
SOIL REACTION-pH				
Paste				
1:5 H$_2$O		9.7	9.2	9.6
1:2 0.01 M CaCl$_2$				
ORGANIC CARBON	(percent)			
AVAILABLE PHOSPHORUS	(ppm)			
Ca CO$_3$ EQUIVALENT	(percent)			
GYPSUM REQUIREMENT	(me/100g)	+3.72	+1.70	+5.1
SATURATION EXTRACT				
Saturation Percentage		45.2	54.9	59.2
EC$_e$@ 25°C	(mmhos/cm)	2.30	2.15	1.80
Ca++	(me/1)	0.49	1.87	0.49
Mg++	(me/1)	0.45	2.53	0.36
Na+	(me/1)	24.44	19.47	19.03
K+	(me/1)	0.31	0.69	0.23
CO$_3$-	(me/1)	0.19	0.42	0.00
HCO$_3$-	(me/1)	8.32	7.64	7.69
Cl-	(me/1)	0.29	0.19	0.20
SO$_4$-	(me/1)	16.24	16.66	11.28
NO$_3$-	(me/1)	0.07	0.10	0.24
SAR	(me/1)	36.0	13.0	29.0
Na	(me/100g)	1.10	1.07	1.13
Ca+Mg	(me/100g)	0.04	0.24	0.05
1:5 EXTRACT				
EC$_5$@ 25°C	(mmhos/cm)	0.47	0.43	0.45
Ca+Mg	(me/1)	1.12	0.76	1.81
EXCHANGEABLE SODIUM	(percent)	23.12	8.71	24.85
ACIDITY				
1N KCL exchange acidity				
Total	(me/100g)			
Al+++	(me/100g)			
CATION EXCHANGE CAPACITY	(me/100g)	16.63	20.54	20.43
NaOAc@pH 8.2				
BORON	(mg/1)			

Table 19
Sheet 1 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET
GEOLOGIC DRILL HOLE 81-109

Study Area: Circle 2, Montana
Location. Sec. 4 Twp. 20N. Range 49E.
1550' S. and 25' E. of NW Corner
Climate:
Land Use:
Relief:
Elevation:
Slope Aspect:
Vegetation:
Erosion:
Stoniness:
Drainage:
Cround Water:
Land Form:
Parent Material:
Soil Series:
Soil Classification:
Profile Description By: L. Parish Date:

DETERMINATION		DATA (mg/1)				
Laboratory Number		20,796	20,797	20,798	20,799	20,800
Sack Number						
Depth		10.0-19.5	24.0-44.0	44.0-64.0	67.3-83.0	83.0-90.0
ALUMINUM	Al					
SILVER	Ag					
ARSENIC	As					
BORON	B	1.61	0.70	0.75	1.91	0.79
BARIUM	Ba					
BERYLLIUM	Be					
CADMIUM	Cd	0.02	0.08	0.04	0.12	0.04
COBALT	Co					
CHROMIUM	Cr					
COPPER	Cu	2.40	6.80	1.40	14.0	2.60
IRON	Fe	57.40	128.00	145.00	243.40	140.00
MEPCURY	Hg	0.072	0.072	0.047	0.056	0.034
LITHIUM	Li					
MANGANESE	Mn	47.60	37.40	11.80	28.10	11.20
MOLYBDENUM	Mo	0.29	0.11	0.30	0.43	0.31
NICKEL	Ni	0.90	1.50	0.30	2.90	1.40
PHOSPHOROUS	P					
LEAD	Pb	3.20	5.20	1.60	7.80	2.60
STRONTIUM	Sr					
SELENIUM	Se	<0.1	<0.1	<0.1	<0.1	<0.1
VANADIUM	V					
ZINC	Zn	1.00	2.08	1.00	4.46	5.92

LABORATORY DESCRIPTION

DETERMINATION		DATA				
Laboratory Number		20,796	20,797	20,798	20,799	20,800
Sack Number						
DEPTH	(ft)	10.0-19.5	24.0-44.0	44.0-64.0	67.3-83.0	83.0-90.0
PARTICLE SIZE ANALYSIS	(percent)					
Very Coarse Sand	(2.0-1.0 mm)			1.8		0.2
Coarse Sand	(1.0-0.5 mm)			0.9		0.2
Medium Sand	(0.5-0.25 mm)			0.7		0.3
Fine Sand	(0.25-0.10 mm)			22.4		24.8
Very Fine Sand	(0.10-0.05 mm)			19.5		37.3
TOTAL SAND	(2.0-0.05 mm)	1.4	3.0	45.3	9.2	62.8
SILT	(0.05-0.002 mm)	65.2	66.8	46.0	49.5	31.2
CLAY	(0.002 mm)	33.4	30.2	8.7	31.3	6.0
TEXTURAL CLASS (LAB)		SiCL	SiCL	L	SiCL	VFSL
BULK DENSITY	(g/cm^3)					
HYDRAULIC CONDUCTIVITY	(in/hr)					
6th Hr.		0.05	0.00	0.11	0.00	Tr
24th Hr.		Tr	Tr	0.11	0.00	Tr
SETTLINC VOLUME	(ml)	35.0	46.0	20.0	126.0	86.0
MOISTURE RETENTION	(percent)					
1/10 bar						
1/3 bar						
15 bar		20.3	20.5	1.0	24.2	6.6
SOIL REACTION-pH						
Paste						
1:5 H_2O		8.8	8.9	9.2	9.5	9.5
1:2 0.01 M $CaCl_2$						
ORCANIC CARBON	(percent)					
AVAILABLE PHOSPHORUS	(ppm)					
Ca CO_3 EQUIVALENT	(percent)					
CYPSUM REQUIREMENT	(me/100g)	-0.73	+0.40	-3.60	+4.70	-5.10
SATURATION EXTRACT						
Saturation Percentage		55.1	55.0	32.2	66.4	33.6
EC_e@ 25°C	(mmhoa/cm)	4.00	4.20	6.90	3.70	6.10
Ca++	(me/1)	11.03	7.96	15.92	1.21	3.84
Mg++	(me/1)	20.72	12.94	17.10	1.36	4.79
Na+	(me/1)	21.28	32.38	60.50	37.97	63.13
K+	(me/1)	0.73	0.86	0.73	0.48	0.79
CO_3-	(me/1)	0.00	0.00	0.00	0.00	0.00
HCO_3-	(me/1)	1.46	2.72	1.46	6.95	4.72
Cl-	(me/1)	0.64	0.45	0.87	0.42	1.41
SO_4-	(me/1)	48.09	54.13	91.61	37.48	66.63
NO_3-	(me/1)	3.11	0.32	0.81	0.03	0.00
SAR	(me/1)	5.30	10.00	15.00	34.00	30.00
Na	(me/100g)	1.17	1.78	1.95	2.52	2.12
Ca+Mg	(me/100g)	1.75	1.15	1.06	0.17	0.29
1:5 EXTRACT						
FC_5@ 25°C	(mmhos/cm)	0.72	0.84	0.83	0.73	0.66
Ca+Mg	(me/1)	3.71	2.87	3.07	1.58	0.57
EXCHANCEABLE SODIUM	(percent)	4.65	12.24	21.46	24.27	18.53
ACIDITY						
IN KCL exchange acidity						
Total	(me/100g)					
Al+++	(me/100g)					
CATION EXCHANCE CAPACITY	(me/100g)	16.96	14.57	4.24	19.02	5.65
NaOAc@pH 8.2						
BORON	(mg/1)					

Table 19
Sheet 2 of 2

MISSOURI SOURIS PROJECTS OFFICE
SOIL AND WATER LABORATORY
Bureau of Reclamation
BISMARCK, NORTH DAKOTA

SOIL ANALYSIS DATA SHEET
GEOLOGIC DRILL HOLE 81-109 (cont'd)

Study Area: Circle 2, Montana
Location. Sec. 4 Twp. 20N Range 49E
1550' S. and 25' E. of NW Corner
Climate:
Land Use:
Relief:
Elevation:
Slope Aspect:
Vegetation:
Erosion:
Stoniness:
Drainage:
Ground Water:
Land Form:
Parent Material:
Soil Series:
Soil Classification:
Profile Description By: L. Parish Date:

DETERMINATION		DATA (mg/l)				
Laboratory Number Sack Number		20,801	20,802	20,803	20,804	20,805
Depth		90.0-103.5	103.5-115.0	115.0-125.0	125.0-137.7	147.0-167.0
ALUMINUM	Al					
SILVER	Ag					
ARSENIC	As					
BORON	B	1.49	0.82	0.93	0.93	0.00
BARIUM	Ba					
BERYLLIUM	Be					
CADMIUM	Cd	0.06	0.02	0.04	0.08	0.12
COBALT	Co					
CHROMIUM	Cr					
COPPER	Cu	10.60	0.18	12.00	6.80	14.00
IRON	Fe	260.00	104.20	193.20	230.20	259.20
MERCURY	Hg	0.047	0.028	0.087	0.059	0.069
LITHIUM	Li					
MANGANESE	Mn	37.60	6.40	18.60	37.40	28.60
MOLYBDENUM	Mo	0.37	0.17	0.19	0.38	0.28
NICKEL	Ni	2.40	0.60	1.10	3.30	3.80
PHOSPHOROUS	P					
LEAD	Pb	8.80	2.40	7.00	6.20	9.00
STRONTIUM	Sr					
SELENIUM	Se	<0.1	<0.1	<0.1	<0.1	0.1
VANADIUM	V					
ZINC	Zn	4.52	2.90	2.14	2.22	2.18

LABORATORY DESCRIPTION

DETERMINATION		DATA				
Laboratory Number		20,801	20,802	20,803	20,804	20,805
Sack Number						
DEPTH	(ft)	90.0-103.5	103.5-115.0	115.0-125.0	125.0-137.7	147.0-167.0
PARTICLE SIZE ANALYSIS	(percent)					
Very Coarse Sand	(2.0-1.0 mm)					
Coarse Sand	(1.0-0.5 mm)					
Medium Sand	(0.5-0.25 mm)					
Fine Sand	(0.25-0.10 mm)					
Very Fine Sand	(0.10-0.05 mm)					
TOTAL SAND	(2.0-0.05 mm)	6.6	7.2	7.0	0.8	10.9
SILT	(0.05-0.002 mm)	62.3	48.3	48.9	71.9	48.4
CLAY	(0.002 mm)	31.1	44.5	44.1	27.3	40.7
TEXTURAL CLASS (LAB)		SiCL	SiC	SiC	SiCL	SiC
BULK DENSITY	(g/cm^3)					
HYDRAULIC CONDUCTIVITY	(in/hr)					
6th Hr.		0.00	0.16	0.00	0.00	0.00
24th Hr.		Tr	0.14	0.00	0.00	0.00
SETTLING VOLUME	(ml)	27.0	22.0	172.0	96.0	206.0
MOISTURE RETENTION	(percent)					
1/10 bar						
1/3 bar						
15 bar		24.0	4.4	26.2	23.2	28.0
SOIL REACTION-pH						
Paste						
1:5 H_2O		9.3	9.4	9.7	9.5	9.9
1:2 0.01 M $CaCl_2$						
ORGANIC CARBON	(percent)					
AVAILABLE PHOSPHORUS	(ppm)					
Ca CO_3 EQUIVALENT	(percent)					
GYPSUM REQUIREMENT	(me/100g)	+3.50	+0.45	+7.50	+3.20	+8.90
SATURATION EXTRACT						
Saturation Percentage		53.6	31.4	76.3	56.9	85.2
EC_e@ 25°C	(mmhos/cm)	3.00	3.90	1.90	2.60	2.00
Ca++	(me/l)	0.99	3.84	0.22	0.66	0.38
Mg++	(me/l)	1.09	3.89	0.18	0.81	0.18
Na+	(me/l)	31.47	36.49	19.18	26.73	20.38
K+	(me/l)	0.45	0.61	0.17	0.30	0.17
CO_3-	(me/l)	0.48	0.00	0.33	0.35	0.42
HCO_3-	(me/l)	9.91	3.28	7.94	8.95	9.45
Cl-	(me/l)	0.60	0.48	0.10	0.16	0.15
SO_4-	(me/l)	25.61	41.64	12.74	17.07	9.97
NO_3-	(me/l)	0.00	0.02	0.006	0.007	0.002
SAR	(me/l)	31.00	19.00	43.00	31.00	38.00
Na	(me/100g)	1.68	1.15	1.46	1.52	1.74
Ca+Mg	(me/100g)	0.11	0.24	0.03	0.08	0.05
1:5 EXTRACT						
EC_5@ 25°C	(mmhos/cm)	0.60	0.39	0.57	0.54	0.61
Ca+Mg	(me/l)	1.21	0.50	2.93	1.74	2.37
EXCHANGEABLE SODIUM	(percent)	26.55	17.67	34.30	25.92	38.77
ACIDITY						
1N KCL exchange acidity						
Total	(me/100g)					
Al+++	(me/100g)					
CATION EXCHANGE CAPACITY NaOAc@pH 8.2	(me/100g)	14.24	22.72	20.87	14.89	21.09
BORON	(mg/l)					

Table 20

Criteria Used to Determine Suitability of Overburden Material For Use as Plant Media in Revegetation1/

Parameter	Methodology	Suitable	Limited Suitability	Unsuitable
Texture	Pipette method plus sand sieving	FSL, VFSL, L, SiL, SCL	LFS, SL, CL, SiCL, SC	S, LS, SiC, C
Electrical Conductivity (mmhos/cm)	Saturation extract/conductivity bridge	<4	4-12	>12
pH	Saturated paste/glass electrode	6.0 - 8.4	5.0 - 6.0; 8.4 - 9.0	<5.0; >9.0
Sodium Adsorption Ratio (SAR)	Calculate: Na/ (Ca+Mg)/2; Ca, Mg, and Na in meq/l	<6	6-9 heavy textures 6-12 medium and coarse textures	>9 - heavy textures >12 - medium and coarse textures
Exchangeable Sodium Percentage (ESP)	Ammonium acetate extraction; calculate: Na/CEC x 100%	<5	5-15	>15 2/
Boron (mg/l)	Hot water extraction/carmine method	<5		>5
Selenium (mg/l)	Hydride generation; flameless AA	<2		>2
Molybdenum (mg/l)	Ammonium oxalate extraction; flameless AA or N_2O flame AA - 5000	<1		>1
Copper (mg/l)	DTPA extraction; AA	3/		3/
Manganese (mg/l)	DTPA extraction; AA	<60		>60
Zinc (mg/l)	DTPA extraction; AA	<40		>40
Lead (mg/l)	DTPA extraction; AA	10-15 (pH <6) 15-20 (pH >6)		15 (pH <6) 20 (pH >6)
Cadmium (mg/l)	DTPA extraction; AA	<1		>1
Nickel (mg/l)	DTPA extraction; AA	2-3		>3
Mercury (mg/l)	Extraction by H_2SO_4; flameless AA (quartz cell)	<0.5		>0.5
Iron (mg/l)	-		Not Established	
Nitrate-Nitrogen (mg/l)	-		Not Established	

1/ Applicable only to reclamation study areas in Montana and North Dakota.

2/ Rate 2:1 - Clay texture poor if >10, sand texture if >20.

3/ Suspect level not established - an excessive consumption of molybdenum through ingestation of vegetation may be toxic to animals. This concern is directly related to the Cu:Mo ratio in the plant tissue.

Suitability of Overburden Material for Use as Plant Media in Revegetation - Woodson PRLA Study Area
Drill Hole 81-101

Depth (ft)	Type	Suitability	Limiting Factor(s)
10.0-28.0	Sandy Silt	Limited	Salinity
28.0-44.0	S Sist	Limited	Salinity
44.0-60.0	S Sist	Limited	Salinity
60.0-76.0	S SiST	Suitable	--
76.0-80.0	Ssh	Limited	Texture, Salinity
80.0-84.5	SiSs	Limited	Salinity, % Sodium
121.2-131.0	SiSs	Unsuitable	pH, % Sodium

Legend

Ss - Sandstone
SiSs - Silty sandstone
Css - Clayey sandstone
Sist - Siltstone
S Sist - Sandy siltstone
C Sist - Clayey siltstone
Sh - Shale
Ssh - Sandy shale
Sish - Silty shale
Cbsh - Carbonaceous shale

Le St - Limestone

Table 21
Sheet 2 of 9

Suitability of Overburden Material for Use as Plant Media in Revegetation - Burns Creek Study Area
Drill Hole 81-102

Depth (ft)	Type	Suitability	Limiting Factor(s)
10.0-33.6	S Silt/Gravel	Unsuitable	Texture, Low Cu:Mn
33.6-55.0	S Sist	Unsuitable	Texture
55.0-65.0	S Sist	Suitable	--
65.5-69.0	Cbsh	Unsuitable	Texture
69.0-80.0	C Sist	Limited	Texture
80.0-105.4	C Sist	Suitable	--
106.2-125.0	Sish, SiSs	Limited	Texture
125.0-141.0	Sish, SiSs	Limited	Texture
141.0-147.0	SiSs	Suitable	--
147.0-167.0	S Sist	Limited	Texture
169.8-189.0	Sish	Suitable	--
189.0-209.4	Sish	Suitable	--
219.5-226.6	Sish	Suitable	--
252.1-270.0	S Sist	Suitable	--

Legend

Ss - Sandstone
SiSs - Silty sandstone
Css - Clayey sandstone
Sist - Siltstone
S Sist - Sandy siltstone
C Sist - Clayey siltstone
Sh - Shale
Ssh - Sandy shale
Sish - Silty shale
Cbsh - Carbonaceous shale

Le St - Limestone

Table 21
Sheet 3 of 9

Suitability of Overburden Material for Use as Plant Media in Revegetation - Burns Creek Study Area
Drill Hole 81-103

Depth (ft)	Type	Suitability	Limiting Factor(s)
10.0-30.0	Sand/Gravel	Unsuitable	Texture, Low Cu:Mo
30.0-35.8	SiS/Gravel	Unsuitable	Texture
35.8-47.5	C Sist	Limited	Texture; Low Cu:Mo
47.5-63.5	Sist	Limited	Texture, Low Cu:Mo
63.5-77.0	C Sist	Suitable	--
77.0-88.2	Sish	Unsuitable	Texture
88.2-110.3	Sish, C Sist	Suitable	--
110.8-133.8	C Sist	Unsuitable	Texture
135.0-171.0	Sish, C Sist	Limited	Texture
172.3-200.5	Sish	Limited	Texture
200.5-204.0	S Sist	Suitable	--
240.0-253.0	Sish	Limited	Texture

Legend

Ss - Sandstone
SiSs - Silty sandstone
Css - Clayey sandstone
Sist - Siltstone
S Sist - Sandy siltstone
C Sist - Clayey siltstone
Sh - Shale
Ssh - Sandy shale
Sish - Silty shale
Cbsh - Carbonaceous shale

Le St - Limestone

Table 21
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Suitability of Overburden Material for Use as Plant Media in Revegetation - Upper Thirteenmile Creek Study Area
Drill Hole 81-104

Depth (ft)	Type	Suitability	Limiting Factor(s)
10.0-32.0	SiSs, Sish	Limited	Texture, Salinity
32.0-48.0	Sist	Suitable	--
48.0-57.0	Sish, SiSs	Limited	Salinity
57.0-67.5	Sish	Suitable	--
67.5-73.4	SiSs	Limited	Salinity
73.4-88.5	C Sist	Suitable	--
88.5-94.5	Cbsh	Unsuitable	Texture
94.5-100.5	SiSs	Suitable	--
100.5-111.0	Sish	Limited	Texture
111.0-125.0	S Sist	Limited	Texture
125.0-150.8	Sish	Unsuitable	Texture, Nickel*
164.1-174.2	Sish	Limited	Texture, Nickel*
177.9-202.0	Sish	Suitable	--
211.9-230.0	Sish	Unsuitable	% Sodium

*Alkaline condition of the overburden will reduce the potential for nickel toxicity.

Legend

Ss - Sandstone
SiSs - Silty sandstone
Css - Clayey sandstone
Sist - Siltstone
S Sist - Sandy siltstone

C Sist - Clayey siltstone
Sh - Shale
Ssh - Sandy shale
Sish - Silty shale
Cbsh - Carbonaceous shale

Le St - Limestone

Suitability of Overburden Material for Use as Plant Media in Revegetation - Upper Thirteenmile Creek Study Area
Drill Hole 81-105

Depth (ft)	Type	Suitability	Limiting Factor(s)
10.0-14.0	Sandy Silt	Limited	Salinity
14.0-24.0	Sish	Limited	Salinity
24.0-44.0	Sish	Suitable	--
44.0-49.3	Sh	Suitable	--
51.0-71.0	C Sist	Suitable	--
71.0-94.0	C Sist	Limited	Texture
94.0-101.9	Sh	Limited	Texture, Nickel*
134.0-141.0	Sish, SiSs	Suitable	--

*Alkaline condition of the overburden will reduce the potential for nickel toxicity.

Legend

Ss - Sandstone
SiSs - Silty sandstone
Css - Clayey sandstone
Sist - Siltstone
S Sist - Sandy siltstone
C Sist - Clayey siltstone
Sh - Shale
Ssh - Sandy shale
Sish - Silty shale
Cbsh - Carbonaceous shale

Le St - Limestone

Suitability of Overburden Material for Use as Plant Media in Revegetation - Southwest Glendive Study Area
Drill Hole 81-106

Depth (ft)	Type	Suitability	Limiting Factor(s)
10.0-25.0	Gravel/Sand	Unsuitable	Texture, Manganese*
33.0-57.0	Silty Sand	Suitable	--
57.0-78.0	Fine Sand	Suitable	--
78.0-99.0	Sh	Suitable	--
118.0-130.0	Ssh	Unsuitable	% Sodium
130.0-140.0	Ssh	Unsuitable	% Sodium, Nickel*

*Alkaline condition of the overburden will reduce the potential for manganese and/or nickel toxicity.

Legend

Ss - Sandstone
SiSs - Silty sandstone
Css - Clayey sandstone
Sist - Siltstone
S Sist - Sandy siltstone
C Sist - Clayey siltstone
Sh - Shale
Ssh - Sandy shale
Sish - Silty shale
Cbsh - Carbonaceous shale

Le St - Limestone

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Suitability of Overburden Material for Use as Plant Media in Revegetation - Southwest Glendive Study Area
Drill Hole 81-107

Depth (ft)	Type	Suitability	Limiting Factor(s)
10.0-15.0	Silty Sand	Unsuitable	Texture, Low Cu:Mo
94.0-118.7	Sish	Limited	Texture
134.1-144.0	Sish	Limited	Texture, Nickel*

*Alkaline condition of the overburden will reduce the potential for nickel toxicity.

Legend

Ss - Sandstone
SiSs - Silty sandstone
Css - Clayey sandstone
Sist - Siltstone
S Sist - Sandy siltstone
C Sist - Clayey siltstone
Sh - Shale
Ssh - Sandy shale
Sish - Silty shale
Cbsh - Carbonaceous shale

Le St - Limestone

Suitability of Overburden Material for Use as Plant Media in Revegetation - Circle 2 Study Area
Drill Hole 81-108

Depth (ft)	Type	Suitability	Limiting Factor(s)
15.0-23.0	S Sist, Sish	Limited	Manganese*, Salinity
23.1-46.6	C Sist	Limited	Texture, Salinity
47.2-68.0	C Sist	Limited	Texture, Salinity
68.0-72.5	Sh	Limited	Texture, Salinity
76.8-90.0	S Sist	Unsuitable	% Sodium
90.0-106.8	Sh, S Sist	Unsuitable	% Sodium
110.4-123.0	Ss, Sist	Unsuitable	% Sodium
123.0-147.4	Sish	Unsuitable	% Sodium, pH
149.7-162.8	C Sist	Unsuitable	% Sodium, pH
164.0-179.0	C Sist	Unsuitable	% Sodium, pH
179.0-194.0	C Sist	Unsuitable	% Sodium
194.0-206.4	Sish	Limited	% Sodium
224.8-242.0	Sish	Unsuitable	% Sodium

*Alkaline conditon of the overburden will reduce the potential for manganese toxicity.

Legend

Ss - Sandstone
SiSs - Silty sandstone
Css - Clayey sandstone
Sist - Siltstone
S Sist - Sandy siltstone
C Sist - Clayey siltstone
Sh - Shale
Ssh - Sandy shale
Sish - Silty shale
Cbsh - Carbonaceous shale

Le St - Limestone

Table 21
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Suitability of Overburden Material for Use as Plant Media in Revegetation - Circle 2 Study Area
Drill Hole 81-109

Depth (ft)	Type	Suitability	Limiting Factor(s)
10.0-19.5	Sish	Limited	Texture, Salinity
24.0-44.0	Sish	Limited	Texture, Salinity
44.0-64.0	Ss	Unsuitable	% Sodium, Salinity
67.3-83.0	Sish	Unsuitable	% Sodium, Texture
83.0-90.0	Ss	Unsuitable	% Sodium, Salinity
90.0-103.5	Sish	Unsuitable	% Sodium, Texture
103.5-115.0	Ss	Unsuitable	% Sodium, Texture
115.0-125.0	Sh	Unsuitable	% Sodium, Texture
125.0-137.7	Sh	Unsuitable	% Sodium, Texture
147.0-167.0	Sish	Unsuitable	% Sodium, Texture

Legend

Ss - Sandstone
SiSs - Silty sandstone
Css - Clayey sandstone
Sist - Siltstone
S Sist - Sandy siltstone

C Sist - Clayey siltstone
Sh - Shale
Ssh - Sandy shale
Sish - Silty shale
Cbsh - Carbonaceous shale

Le St - Limestone

Exhibit 1
Sheet 1 of 3

SCREENABLE SOIL CHARACTERIZATION AS RELATED TO LAND RECLAMATION

By
William B. Peters, Luvern L. Resler, and Robert Vader[1]

Soil is characterized by laboratory methods to confirm judgement in field appraisals. There is a tendency among most laboratory activities to "over test"; i.e., perform too many or unnecessary tests on certain soils at the expense of not performing essential or critical testing on particular samples. Also, laboratory activities tend to emphasize comprehensive analyses of samples from master sites and neglect selection, sequence, and quality control in mass testing performed on a screenable basis. The latter-type testing is frequently handled as routine work utilizing the least dependable personnel and considered not worthy of competent and close supervision. Thus, too often the screenable laboratory testing becomes a liability rather than an asset in supporting land classification surveys. Because the screenable testing represents coverage of areas involving a high sampling density, it serves as an extremely important input into land catergorization. Therefore, it should be administered for performance with respect to both quality and quantity commensurate with the goals and objectives of the investigation.

The objective of characterizing soil and overburden will be to support judgment in estimating land reclamation potential. (Overburden refers to the material consolidated or unconsolidated overlying minable resources in relation to surface mining.) Thus, the laboratory analyses must be performed on an action program basis and serve a practical purpose. Therefore, it is essential the physical and chemical characteristics of the soil and overburden be appraised in relation to edaphology; i.e., a medium suitable for the support of plant growth, rather than pedology.

Because the laboratory studies should serve to support field appraisals, all laboratory work should be closely coordinated with fieldwork. For full effectiveness, laboratory studies must be preceded by field studies. The number and type of studies will be determined by area conditions - particularly variability, the controlling project specifications, and needs. There should be a joint plan between field and laboratory investigations prior to taking of samples if maximum utilization of data is to be obtained. Problems should be studied rather than standard or routine tests made (Kellogg, 1962).

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[1] Head and Soil Scientists, respectively, Land Utilization Section, Resource Analysis Branch, Division of Planning Coordination, U.S. Department of the Interior, Bureau of Reclamation, Denver, Colorado, U.S.A.

Exhibit 1
Sheet 2 of 3

In submitting soil samples for laboratory characterizations, the laboratory should be furnished with pertinent field appraisals along with the tentative land utilization and quality designation. The soil and subsoil samples should represent genetic horizons with no more than 60-cm depth per sample. Substrata samples should represent uniform overburden with no more than 200 cm per sample unless drill hole diameters preclude obtaining sufficient material for laboratory and greenhouse studies.

The first priority in laboratory characterization should be accomplished by direct and indirect measurements for evaluating soil structure and its stability, soil-cation-exchange capacity or surface area, and soil reaction. After this is accomplished, then consideration should be given to testing that confirms, explains the causes of phenomena previously observed or predicted, reveals the presence of toxic elements (salinity level, boron content, alkali, acidity, reduction products, etc.), and indicates what and how much is required to cope with the soil deficiency under eventual field conditions and the moisture regimen expected to prevail (Peters, 1965).

Based on present knowledge of the area, the support characterizations should include field measurements for water movement and retention in soil and laboratory determinations for structure stability (Gardner, 1945) through measurements of floc volume and hydraulic conductivity of fragmented samples; moisture retentivity at 15-bars pressure; soil reaction by measurement of pH in water and neutral salt solution; soil salinity by measurement of specific electrical conductance of soil-water extracts; soil solution concentration and composition including sodium and calcium plus magnesium; cation exchange capacity; exchangeable cation status; residual gypsum; gypsum requirement; acid soluble carbonates; and others.

Samples collected in a reduced state may be alkaline or neutral while reduced, but acid when oxidized. Therefore, we should be on the "lookout" for such conditions and characteristics and assure reduced material is also analyzed in an aerated condition. Samples exhibiting acidity upon oxidation should be further analyzed to ascertain reduction products associated with the observed phenomenon.

Should conventional acidity; i.e., other than oxidation product, be encountered, the testing will be expanded to include acidity by measurement of neutral salt exchange acidity including aluminum, titratable acidity (amount of acidity neutralized at a selected pH), and soluble aluminum.

In screenable testing, the characterization for moisture retentivity at pressures less than 15 bars is not recommended unless a suitable use can be established. Measurements of moisture retentivity at 15-bars pressure are recommended because water content at this potential is usually correlated with several characteristics including amount and kind of clay, surface area, and cation exchange capacity. Moisture percentages at this potential would probably not be applicable in simulating water content at wilting for native vegetation.

Exhibit 1
Sheet 3 of 3

In initial screening, diluted soil-water suspensions may be substituted for the time-consuming, saturated soil extracts in measuring electrical conductance provided limitations are ascertained. The reliability of higher moisture contents even as a tool in screening depends on the kind of salts present. For chloride salts, the results will be only slightly affected by the moisture content, but if sulfate or carbonate salts, which have relatively low solubility, are present in appreciable quantities, the apparent amount of soluble salt will depend on the soil-water ratio (Richards, 1954).

We do not concur in the practice of characterizing vast numbers of samples for textural class through measurements of particle-size distribution. This blanket laboratory analysis for soil textural class is neither required nor desired. Particle-size analysis should be limited to master site characterization, the occasional confirmation of field textural appraisals, and the training of new employees.

In the screenable characterization of samples, a procedure for the sequence of testing and screening of samples should encompass the following phases. Under Phase 1 of the scheme, all samples would be characterized for (1) soil structure stability thorugh measurement of hydraulic conductivity on a fragmented sample basis during the 6th and 24th hours and volume of wet settled floccules, (2) moisture retentivity at 15-bars pressure, (3) electrical conductivity of soil-water extract, and (4) pH in water and in 0.01 molar calcium chloride solution.

In the second phase, selected samples suspected through the testing results of Phase 1 to be salt affected should be characterized for electrical conductivity of the saturation extract and sodium adsorption ratio.

In the third phase, selected samples suspected through the testing results of Phase 1 and 11 to be salt affected with respect to sodium will be tested for either gypsum requirement or residual gypsum, depending on salinity levels and associated pH values. Residual gypsum will be estimated by measuring calcium plus magnesium in a 1:5 soil-water ratio extract and reported in milliequivalents per 100 grams.

In the fourth phase, selected samples suspected through testing results of Phase 1 to be highly acid and low in base saturation and nonsaline should be further characterized for bases specifically sodium and calcium plus magnesium and acidity including the aluminum component extractable with a neutral salt; i.e., 1.0N potassium chloride. This will enable computation of effective soil-cation-exchange capacity; i.e., CEC at soil pH and the exchangeable aluminum percentage of this CEC.

In the fifth phase, selected samples having been characterized during Phases 1, 11, and 1V to be saline acid would be characterized for soluble aluminum.

The above-described characterization program would not preclude testing on a "complete analysis" basis on samples from master sites.

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Soils and Water Laboratory Procedures and References

I. Soil Characterization

A. Physical Properties of Soils

1. Disturbed Hydraulic Conductivity is determined by the use of plastic tubes (Richards, et al., 1954, Diagnosis and Improvements of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 34b:112-113).

2. Settling Volume, Imoff Cones, (Series 510 Land Classification Techniques and Standards 517.5.7).

3. Particle Size Analyses are determined by pipeting and analysis (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 41:122-123).

4. Particle Density, (C. A. Black, et al., Methods of Soil Analysis Part 1, Agronomy No. 9, American Society of Agronomy, 29:371-373), (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 39:122).

5. Bulk Density, (C. A. Black, et al., Methods of Soil Analysis Part 1, Agronomy No. 9, American Society of Agronomy, 30-1:374-390), (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 38:121-122).

6. Moisture Retention is determined by ceramic plates (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 29, 30 and 31:109-110).

7. Field Capacity - field determination.

8. Water holding capacity - determined by calculation: field capacity-wilting point x bulk density x 48 inches = water holding capacity per 48 inches of soil.

B. Soluble Cations and Anions

1. Carbonates and bicarbonates are determined with automated Fisher titralyzer II by acid titration and chlorides are determined with automated Fisher titralyzer II, Specific Ion (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 82:145-146 and 84:146), (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 62-3.4.1:945-947 and 62-3.5.1:947-948), (M. J. Taras, et al., Standard Methods for the Examination of Water and Wastewater; Thirteenth Edition, for carbonate and bicarbonate only 102:52-56), (Bear, et al., Chemical Analysis of Soils, 1964), and (Brown,

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Skougstad and Fishman, Techniques of Water Resources Investigation of USGS, Chapter AI, "Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases," Book 5 - Laboratory analysis for chloride only, p. 69).

2. Phosphorus soluble in sodium bicarbonate and Automated Ascorbic Acid (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 73-4.4:1044-1049), (EPA Methods for Chemical Analysis of Water and Wastes, 1979, EPA-600 4-79-020, 365.1:365.1-1-365.1-9).

3. Nitrate-Nitrite are determined by phenoldsulfonic acid and by Automated cadmium reduction (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60), (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 84.5.3:1216-1219) and (M. J. Taras, et al., Standard Methods for the Examination of Water and Wastewater, 1971, Thirteenth Edition, 133:233-237), (Methods for Chemical Analysis of Water and Wastes, 1979 EPA-600 4-79-020, 353.2:353.2-1-353.2-7).

4. Sulfate is determined by Automated Methyl Thymol Blue and turbidimetric, (EPA Methods for Chemical Analysis of Water and Wastes, 1979 EPA-600 4-79-020, 375.2:375.2-1-375.2-4), (M. J. Taras, et al., Standard Methods for the Examination of Water and Wastewater, 1971 Thirteenth Edition, 156C: 334-336).

5. Sodium, Potassium, Calcium and Magnesium are determined by Automated atomic absorption (Perkin-Elmer, Analytical Method for Atomic Absorption Spectrophotometry, 1973), and (Brown, Skougstad and Fishman, Techniques of Water Resources Investigation of USGS, Chapter AI, "Methods of Collection and Analysis of Water Samples for Dissolved Minerals and Gases," Book 5 - Laboratory Analysis, 66, 109, 133 and 143).

C. Trace Metals

1. Trace Metals are determined by atomic absorption with flame or graphite furnace (Perkin-Elmer, Analytical Method for Atomic Absorption Spectrophotometry, 1973), (Brown, Skougstad and Fishman, Techniques of Water Resources Investigation of USGS, Chapter AI, "Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases," Book 5 - Laboratory Analysis, 50-157), (M. J. Taras, et al., Standard Methods for the Examination of Water and Wastewater, 1971 Thirteenth Edition), and (Methods for Chemical Analysis of Water and Wastes, 1979 EPA-600-4-79-020).

D. Chemical Soil Characterization

1. pH reading of 1:5 Soil Suspension (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook

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No. 60, 21b:102), (C. A. Black, et al., Methods of Soil Analysis, Part 2 Agronomy No. 9, American Society of Agronomy 60-3.4:922-923) and (Bear, et al., Chemical Analysis of Soils, 1964).

2. pH reading in $CaCl_2$ Solution (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 60-3.5:923).

3. Saturation Extract taken from saturated soil paste using Bariod filter press and measuring soluble salts by use of electrode conductivity bridge (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 2 and 3:84-88, 27:107 and 4:89-90), (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 62-1:933-988) and (Bear, et al., Chemical Analysis of Soils, 1964).

4. Exchangeable Sodium and Potassium are extracted by ammonium acetate solution. Cation-Exchange Capacity determined using Sodium Acetate as index ion and follow with Ammonium Acetate (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 18:100-101 and 19:101) and (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9 American Society of Agronomy 72-3:1033, 72-3.2.1:1034 and 57-1:891-895).

5. Exchangeable Sodium Percentage is determined by calculation relationship being $\frac{Na}{CEC}$ x 100 (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 20a:101).

6. Gypsum determined by increase in soluble calcium plus magnesium content upon dilution (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 22c:104).

7. Gypsum Requirement (Richards, et al., 1954, Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 22d:104-105).

8. Boron was determined by extraction with hot water (C. A. Black, et al., Methods of Soil Analysis, Part 2, Agronomy No. 9, American Society of Agronomy 75-4:1062-1063 and 62-3.6 949-951).

9. Percent Organic Carbon is determined with Technicon Auto Analyzer II.

10. Total Carbonate expressed as % calcium carbonate, acid-neutralization, (C. A. Black, et al., Methods of Soil Analysis Part 2, Agronomy No. 9, American Society of Agronomy, 91-4:1387-1388), (Richards et al., 1954 Diagnosis and Improvement of Saline and Alkali Soils, USDA Agriculture Handbook No. 60, 23c:105-106).

11. SAR (sodium adsorption ratio) determined by calculation:
SAR = Na/$\sqrt{(Ca + Mg)/2}$; Ca, Mg, and Na in meq/l.

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GLOSSARY

Alluvium - A general term for clay, silt, sand, gravel, or similar unconsolidated detrital material deposited by a stream or other body of running water as a sorted or semisorted sediment in the bed of the stream or on its flood plain or delta, or as a cone or fan at the base of a mountain slope.

Annual Plant (annuals) - A plant that completes its life cycle and dies in 1 year or less.

Aspect - The direction toward which a slope faces. Exposure.

Available Nutrient - The part of the supply of a plant nutrient in the soil that can be taken up by plants at rates and in amounts significant to plant growth.

Available Water - The part of the water in the soil that can be taken up by plants at rates significant to their growth. Usable: obtainable.

Bedrock - Any consolidated material (shale, sandstone, etc.) soft, weathered or hard that has remained in place and is relatively unchanged.

Broadcast Seeding - Scattering seed on the surface of the soil. Contrast with drill seeding which places the seed in rows in the soil.

Buffer - Substances in soil or water that act chemically to resist changes in reaction of pH.

Calcareous Soil - Soil containing sufficient calcium carbonate (often with magnesium carbonate) to effervesce visibly when treated with cold 0.1 normal hydrochloric acid.

Capillary Water - The water held in the "capillary" or small pores of a soil, usually with tension greater than 60 centimeters of the water. Much of this water is considered to be readily available to plants.

CFS, Cubic feet per second - measurement of water flow.

Channel Stabilization - Erosion prevention and stabilization of velocity distribution in a channel, using jetties, drops, revetments, vegetation, and other measures.

Clay (soils) - (1) A mineral soil separate consisting of particles less than 0.002 millimeter diameter. (2) A soil textural class. (3) (engineering) A fine-grained soil that has a high plasticity index in relation to the liquid limits.

Colluvium - A general term applied to loose, heterogeneous (mixed) deposits of soil material and/or rock fragments near the base of rather steep slopes. The deposits have accumulated through mass wasting (slides), soil creep, and local wash.

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Compaction - The closing of the pore spaces among the particles of soil and rock, generally caused by running heavy equipment over the area, as in the process of leveling the overburden material of strip mine banks.

Companion Crop - (See Nurse Crop).

Conifer - A tree belonging to the order Coniferae, usually evergreen with cones and needle-shaped or scale-like leaves and producing wood known commercially as "softwood."

Contour - An imaginary line connecting points of equal height above sea level as they follow the relief of the terrain.

Cool-Season Plant - A plant that makes its major growth during the cool portion of the year, primarily in the spring but in some localities in the winter.

Deciduous - Refers to a tree that sheds all its leaves every year at a certain season.

Deep Chiseling - Deep chiseling is a surface treatment that loosens compacted spoils. The process creates a series of parallel slots on the contour in the spoils surface which impedes water flows and markedly increases infiltration.

Density, Forage - The percent of ground surface which appears to be completely covered by vegetation when viewed directly from above.

Density, Stand - Density of stocking expressed in number of trees per acre.

Dissolved Solids - The difference between the total and suspended solids in water.

Disturbed Land - Land on which excavation has occurred or upon which overburden has been deposited, or both.

Dozer or Bulldozer - Tractor with a steel plate or blade mounted on the front end in such a manner that it can be used to cut into earth or other material and move said material primarily forward by pushing.

Ecology - The science that deals with the mutual relation of plants and animals to one another and to their environment.

Ecosystem - A total organic community in a defined area or time frame.

Effective Precipitation - That portion of total precipitation that becomes available for plant growth. It does not include precipitation lost to deep percolation below the root zone or to surface runoff.

Effluent - Any water flowing out of the ground or from an enclosure to the surface flow network.

Exhibit 3
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Environment - All external conditions that may act upon an organism or soil to influence its development, including sunlight, temperature, moisture and other organisms.

Erodibility - The relative ease with which one soil erodes under specified conditions of slope as compared with other soils under the same conditions; this applies to both sheet and gully erosion.

Erosion - The wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep. Detachment and movement of soil or rock fragments by water, wind or ice, or gravity.

Essential Element (plant nutrition) - A chemical element required for the normal growth of plants.

Evapotranspiration - A collective term meaning the loss of water to the atmosphere from both evaporation and transpiration by vegetation.

Excavation - The act of removing overburden material.

Fertilizer - Any natural or manufactured material added to the soil in order to supply one or more plant nutrients.

Fertilizer Grade - The guaranteed minimum analysis in whole numbers, in percent, of the major plant nutrient elements contained in a fertilizer material or in a mixed fertilizer. For example, a fertilizer with a grade of 20-10-5 contains 20 percent nitrogen (N), 10 percent available phosphoric acid (P_2O_5), and 5 percent water soluble potash (K_2O). Minor elements may also be included. Recent trends are to express the percentages in terms of the elemental fertilizer [nitrogen (N), phosphorous (P), and potassium (K)].

Fill - Depth to which material is to be placed (filled) to bring the surface to a predetermined grade. Also, the material itself.

Forage - Unharvested plant material which can be used as feed by domestic animals. Forage may be grazed or cut for hay.

Forest Land - Land bearing a stand of trees at any age or stature, including seedlings and of species attaining a minumum of 6 feet average height at maturity or land from which such a stand has been removed but on which no other use has been substituted. The term is commonly limited to land not in farms; forests on the farms are commonly called woodland or farm forests.

Germination - Sprouting; beginning of growth.

Gradation - A term used to describe the series of sizes into which a soil sample can be divided.

Grain Size - Physical size of soil particle, usually determined by either sieve or hydrometer analysis.

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Ground Cover - Any living or dead vegetative material producing a protective mat on or just above the soil surface.

Ground Water - Subsurface water occupying the saturation zone, from which wells and springs are fed. In a strict sense the term applies only to water below water table. Also called plerotic water; phreatic water.

Growing Season - Determined by the Lowery-Johnson Method.

Gully Erosion - Removal of soil by running water with formation of deep channels that cannot be smoothed out completely by normal cultivation.

Hydroseeding - Dissemination of seed hydraulically in a water medium. Mulch, lime, and fertilizer can be incorporated into the sprayed mixture.

Impervious - Prohibits fluid flow.

Infiltration - The downward entry of water into the land surface.

Intermittent Stream - A stream or portion of a stream that flows only in direct response to precipitation. It receives little or no water from springs and is dry for a large part of the year.

Land Classification - Classification of specific bodies of land according to their characteristics or to their capabilities for use. A use capability classification may be defined as one based on both physical and economic considerations according to their capabilities for man's use, with sufficient detail of categorical definition and cartographic (mapping) expression to indicate those differences significant to men.

Land Use Planning - The development of plans for the uses of land that, over long periods, will best serve the general welfare, together with the formulation of ways and means for achieving such uses.

Leaching - The removal of materials in solution by the passage of water through soil.

Leachate - Liquid that has percolated through a medium and has extracted dissolved or suspended materials from it.

Legume - A member of the legume or pulse family, leguminosae. One of the most important and widely distributed plant families. Includes many valuable food and forage species, such as the peas, beans, peanuts, clovers, alfalfas, sweet clovers, lespedezas, vetches and kudzu. Practically all legumes are nitrogen-fixing plants.

Lime - From strictly chemical standpoint, refers to only one compound, calcium oxide (CaO); however, the term lime is commonly used in agriculture to include a great variety of materials which are usually composed of the oxide, hydroxide, or carbonate of calcium or of calcium and magnesium. The most commonly used forms of agricultural lime are ground limestone, marl, and oyster shells (carbonates), hydrated lime (hydroxides), and burnt lime (oxides).

Quicklime - limestone + heat (calcined), CaO
Hydrated Line - quicklime + H_2O $Ca(OH)_2$
Slaked lime - same as hydrated but slaking equipment is used for adding water
Milk of lime - water mixture containing lime in solution + lime in suspension

Micro-Climate - A local climatic condition near the ground resulting from modification of relief, exposure, or cover.

Micro-Nutrients - Nutrients in only small, trace, or minute amounts.

Mined-Land - Land with new surface characteristics due to the removal of mineable commodity by surface mining methods and subsequent surface reclamation.

Mulch - A natural or artificial layer of plant residue or other materials placed on the soil surface to protect seeds, to prevent blowing, to retain soil moisture, to curtail erosion, and to modify soil temperature.

Natural Revegetation - Natural reestablishment of plants; propagation of new plants over an area by natural processes.

Natural seeding (Volunteer) - Natural distribution of seed over an area.

Neutralization - The process of adding an acid or alkaline material to water or soil to adjust its pH to a neutral position.

Neutral Soil - A soil in which the surface layer, at least from normal plow depth, is neither acid nor alkaline in reaction. For most practical purposes, soil with a pH ranging from 6.6 through 7.3.

Nitrogen Fixation - The conversion of atmospheric (free) nitrogen to nitrogen compounds. In soils the assimilation of free nitrogen from the air by soil organisms (making the nitrogen eventually available to plants). Nitrogen fixing organisms associated with plants such as the legumes are called symbiotic; those not definitely associated with plants are called nonsymbiotic.

Nurse Crop - A planting or seeding that is used to protect a tender species during its early life. A nurse crop is usually temporary and gives away to the permanent crop. Sometimes referred to as a companion crop.

Nutrients - Any element taken into a plant that is essential to its growth.

Overburden - Barren rock material, usually unconsolidated, overlying a mineral deposit and which must be removed prior to mining.

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Percolation - Downward movement of water through soils.

Permeability - The measure of the capacity for transmitting a fluid through the substance. In this report the substance is overburden (soil and bedrock).

pH - The symbol or term refers to a scale commonly used to express the degrees of acidity or alkalinity. On this scale pH of 1 is the strongest acid, pH of 14 is the strongest alkali, pH of 7 is the point of neutrality at which there is neither acidity or alkalinity. pH is not a measure of the weight of acid or alkali contained in or available in a given volume (-Log of H+ activity).

Pollution - Environmental degradation resulting from man's activities or natural events.

Pond - A body of water of limited size either naturally or artificially confined and usually smaller than a lake.

Rain - (1) Heavy--Rain which is falling at the time of observation with an intensity in excess of 0.30 in. per hr (over 0.03 inch in 6 min).
(2) Light--Rain which is falling at the time of observation with an intensity of between a trace and 0.10 in. per hr (0.01 inch in 6 min).
(3) Moderate--Rain which is falling at the time of observation with an intensity of between 0.11 in. per hr (0.01+ inch in 6 min) and 0.30 in. per hr (0.03 inch in 6 min).

Range Land - The natural vegetation is predominantly grasses, grasslike plants, forbs, or shrubs.

Percolation Rate - Usually expressed as a velocity, at which water moves through saturated granular material. The term is also applied to quantity per unit or time of such movement, and has been used erroneously to designate infiltration rate or infiltration capacity.

Reclamation - The process of reconverting mined land to its former or other productive uses.

Reconstructed Profile - The result of selective placement of suitable overburden material on reshaped spoils.

Recreation Land - Land and water used, or usable primarily as sites for outdoor recreation facilities and activities.

Reforestation - The natural or artificial restocking of an area with forest trees.

Regrading - The movement of earth over a depression to change the shape of the land surface. A finer form of backfilling.

Rehabilitation - Implies that the land will be returned to a form and productivity in conformity with a prior land use plan, including a stable ecological state that does not contribute substantially to environmental deterioration and is consistent with surrounding aesthetic values.

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Revegetation - The reestablishment of a vegetative cover following land disturbance.

Ripping - The act of breaking, with a tractor-drawn ripper or long angled steel tooth, compacted spoils or rock into pieces small enough to be economically excavated or moved by other equipment as a scraper or dozer.

Runoff - That portion of the rainfall that is not absorbed by the deep strata: is utilized by vegetation or lost by evaporation or may find its way into streams as surface flow.

Saline-Sodic Soil - A soil having a combination of a harmful quantity of soluble salts and either a high degree of sodicity or a high amount of exchangeable sodium, or both, so distributed in the soil profile that the growth of most crop plants is less than normal.

Saline Soil - A soil containing enough soluble salts to impair its productivity for plants but not containing an excess of exchangeable sodium.

Sandstone - A cemented or otherwise compacted detrital sediment composed predominantly of quartz grains, the grades of the latter being those of sand.

Saturation - Completely filled; a condition reached by a material, whether it be in solid, gaseous, or liquid state, which holds another material within itself in a given state in an amount such that no more of such material can be held within it in the same state. The material is then said to be saturated or in a condition of saturation.

Sediment - Solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice and has come to rest on the earth's surface either above or below sea level.

Sediment Basin - A reservoir for the confinement and retention of silt, gravel, rock, or other debris from a sediment-producing area.

Seedbed - The soil prepared by natural or artificial means to promote the germination of seed and growth of seedlings.

Seep - A more or less poorly defined area where water oozes from the earth in small quantities.

Shale - Sedimentary or stratified rock structure generally formed by the consolidation of clay or clay-like material.

Silt - Small mineral soil grains, the particles of which range in diameter from 0.05 to 0.002 mm (or 0.02-0.002 mm in the international system).

Soil (See Acid Soil and Alkaline Soil) - Surface layer of the earth, ranging in thickness from a few inches to several feet composed of finely divided rock debris mixed with decomposing vegetative and animal matter which is capable of supporting plant growth.

Soil Amendment - Any substance used to alter one or more of the many soil properties. These include soil conditioning agents, fertilizers, lime and manures, to name a few.

Soil Conserving Crops - Crops that prevent or retard erosion and maintain or replenish rather than deplete soil organic matter.

Soil Porosity - The degree to which the soil mass is permeated with pores or cavities. It is expressed as the percentage of the whole volume of the soil which is unoccupied by solid particles.

Soil Profile - A vertical section of the soil through all its horizons and extending into the parent material.

Soil Structure - The combination or arrangement of primary soil particles into secondary particles, units, or peds.

Solum - The upper part of a soil profile, above the parent material, in which the processes of soil formation are active. The solum in natural soils includes the A and B horizons. Usually the characteristics of the material in these horizons are quite unlike those of the underlying parent material. The living roots and other plant life and animal life characteristic of the soil are largely confined to the solum.

Spoil - The overburden or non-coal material removed in gaining access to the coal or mineral material in surface mining.

Spoil Bank (Spoil Pile) - Area created by the deposited soil or overburden material prior to backfilling. Also called cast overburden.

Stratified - Composed of or arranged in, strata or layers, as stratified alluvium. The term is applied to geological materials. Those layers in soils that are produced by the processes of soil formation are called horizons, while those inherited from parent material are called strata.

Strip - To mine a deposit by first taking off the overlying burden.

Stripping - The removal of earth or non-ore rock materials as required to gain access to the ore or mineral materials wanted. The process of removing overburden or waste material in a surface mining operation.

Subsoil - The B horizon of soils with distinct profiles. In soils with weak profile development, the subsoil can be defined as the soil below the plowed soil (or its equivalent of surface soil) in which roots normally grow. Although a common term, it cannot be defined accurately. It has been carried over from early days when "soil" was conceived only as the plowed soil and that under it as "subsoil."

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Substratum - Alluvial, colluvial, glacial, or bedrock material that underlies the soil profile.

Surface Mining - Refers to a procedure of mining which entails the complete removal of all material from over the resource to be mined in a series of rows or strips; also referred to as "strip mining."

Surface Soil - The upper part of arable soils commonly stirred by tillage implements or an equivalent depth (5 to 8 minches) in non-arable soils.

Suspended Soilids - Sediment which is in suspension in water but which will physically settle out under quiescent conditions (as differentiated from dissolved material).

Terrace - Sloping ground cut into a succession of benches and steep inclines for purposes of cultivation or to control surface runoff and minimize soil erosion.

Terraced Slope - A slope that is intersected by one or more terraces.

Texture (Soils) - Refers to the fineness or coarseness of a soil. Specifically, it refers to the relative proportions of the various soil separates (sand, silt, clay) in a given soil.

Topsoiling Material - Material that is well suited for plant media. Desired characteristics include: fertile, good tilth, permeable, contains organic matter, nonsaline, nonsodic and has water stable aggregates.

Tilth - The physical condition of a soil in respect to its fitness for the growth of a specified plant.

Topography - The shape of the ground surface, such as hills, mountains, or plains. Steep topography indicates steep slopes or hilly land; flat topography indicates flat land with minor undulations and gentle slopes.

Toxic Spoil (See also Acid Spoil) - Includes acid spoil with pH below 4.0. Also refers to spoil containing excessive levels of exhangeable sodium or trace elements (i.e., selenium, lead, etc.).

Transpiration - The normal loss of water vapor to the atmosphere from plants.

Unconsolidated (soil material) - Soil material in a form of loose aggregation.

Vegetation - General term including grasses, legumes, shrubs, and trees naturally occurring and planted intentionally.

Vegetative Cover - The entire vegetative canopy on an area.

Volunteer - Springing up spontaneously or without being planted; a volunteer plant.

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Weathering - The group of processes, such as chemical action of air and rainwater and of plants and bacteria and the mechanical action of changes in temperature, whereby rocks, on exposure to the weather, change in character, decay, and finally crumble.

Wildlife - Undomesticated vertebrate animals, except fish, considered collectively.

APPENDIX D

GREENHOUSE

Table 23
Sheet 1 of 3

Soil/Overburden Preplant Analysis Percent Sand, Silt, and Clay and Saturation Percentage

Sample	% Sand	% Silt	% Clay	Sat. %
G-159	33.5	53.3	13.2	45.2
G-160	22.1	60.8	17.1	33.4
G-161	0.7	91.3	8.0	50.1
G-162	2.8	86.6	10.6	39.9
G-163	1.0	87.6	11.4	40.5
G-164	0.7	65.6	33.7	49.8
G-165	32.3	55.8	11.9	35.4
G-166	18.0	58.9	23.1	38.8
G-167	10.7	60.6	28.7	45.1
G-168	1.6	64.7	33.7	48.7
G-169	4.3	60.5	35.2	42.4
G-170	13.6	67.3	19.1	43.6
G-171	16.0	57.9	26.1	41.5
G-172	12.8	56.4	30.8	40.0
G-173	15.1	59.5	25.4	41.9
G-174	28.0	52.0	20.0	35.0
G-175	37.0	45.4	17.6	33.1
G-176	21.6	67.2	11.2	49.6
G-177	26.4	54.6	19.0	42.3
G-178	5.3	81.3	13.4	35.7
G-213	16.2	67.8	16.0	47.5
G-214	8.7	67.3	24.0	44.4
G-215	19.2	63.5	17.3	37.0
G-216	1.8	75.8	22.4	40.6
G-217	26.3	55.7	18.0	34.8
G-218	27.5	54.0	18.5	36.9

Soil/Overburden Preplant Analysis
Salinity (EC), Exchangeable Sodium Percentage (ESP), and Sodium Adsorption Ratio (SAR)

Sample	ECe x 10^3 (mmhos/cm)	ESP	SAR
G-159	0.62	0.0	0.1
G-160	0.46	0.7	0.3
G-161	3.40	1.9	2.8
G-162	4.40	6.0	4.1
G-163	5.60	4.1	4.6
G-164	7.00	4.1	3.3
G-165	0.54	0.0	0.1
G-166	1.70	2.7	2.3
G-167	2.40	3.6	2.9
G-168	4.20	4.2	3.2
G-169	5.20	6.0	3.6
G-170	0.70	0.0	0.3
G-171	0.40	0.7	0.4
G-172	0.56	2.6	2.3
G-173	5.00	5.0	4.7
G-174	5.60	7.0	5.3
G-175	8.20	9.9	9.3
G-176	0.82	0.0	0.1
G-177	0.50	0.5	0.3
G-178	1.36	6.9	6.0
G-213	0.68	<0.1	0.1
G-214	4.10	6.2	6.3
G-215	14.00	20.9	16.9
G-216	17.00	26.7	19.3
G-217	19.00	22.4	19.5
G-218	22.00	23.5	21.4

Table 23
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Soil/Overburden Preplant Analysis
Cation Exchange Capacity (CEC), Calcium (Ca), and Magnesium (Mg)

Sample	CEC (meq/100 g)	Ca (meq/l)	Mg (meq/l)
G-159	14.0	3.6	1.7
G-160	8.8	1.0	2.8
G-161	5.3	4.7	26.9
G-162	6.7	7.1	32.3
G-163	7.3	0.9	47.3
G-164	13.5	20.5	61.6
G-165	16.2	3.6	1.7
G-166	13.6	2.4	9.0
G-167	12.4	1.8	17.0
G-168	13.9	3.2	33.5
G-169	13.0	7.4	42.1
G-170	17.8	4.8	1.9
G-171	14.4	2.1	1.6
G-172	12.7	0.9	1.9
G-173	11.0	21.7	24.7
G-174	9.2	20.8	29.7
G-175	8.1	19.4	38.2
G-176	16.3	5.1	2.7
G-177	14.0	2.1	2.1
G-178	12.8	0.8	3.8
G-213	18.5	4.6	1.3
G-214	12.8	11.5	14.0
G-215	8.6	18.9	84.9
G-216	8.6	24.2	95.4
G-217	7.6	33.5	103.5
G-218	8.1	32.9	98.7

Table 24
Sheet 1 of 2

Soil/Overburden Preplant Analysis Plant-Available Phosphorus (P), Potassium (K), Zinc (Zn), and Iron (Fe)

Sample	P/PPM	K/PPM	Zn/PPM	Fe/PPM
G-159	0	73	.1	1.3
G-160	0	40	.1	1.9
G-161	0	26	.5	7.4
G-162	0	35	.5	7.2
G-163	0	39	.6	5.7
G-164	0	58	.9	3.4
G-165	1	57	.1	.1
G-166	0	28	.1	1.0
G-167	0	32	.1	.4
G-168	0	44	.1	.1
G-169	0	37	.1	.4
G-170	6	118	1.1	.7
G-171	0	31	.1	.9
G-172	0	29	.1	1.4
G-173	0	35	.1	.1
G-174	0	28	.1	.4
G-175	0	21	.2	.7
G-176	1	107	.3	.1
G-177	0	32	.1	2.5
G-178	0	41	.1	.5
G-213	0	135	.1	.1
G-214	0	42	.1	.2
G-215	0	32	.1	1.5
G-216	0	35	.2	.9
G-217	0	27	.3	1.3
G-218	0	27	.2	.5

Table 24
Sheet 2 of 2

Soil/Overburden Preplant Analysis
Plant - Available Manganese (Mn), Copper (Cu), Nickel (Ni), Cadmium (Cd), and Lead (Pb)

Sample	Cu/PPM	Mn/PPM	Ni/PPM*	Cd/PPM*	Pb/PPM*
G-159	.1	6.2	.9	.01	.32
G-160	.1	12.0	.7	0.00	.24
G-161	.1	39.0	.7	0.00	.32
G-162	.1	41.0	.8	0.00	.28
G-163	.1	45.0	.8	0.00	.29
G-164	.1	61.0	1.2	.01	.91
G-165	.1	2.8	1.1	.03	.33
G-166	.1	3.2	.9	.01	.25
G-167	.1	6.7	.8	0.00	.13
G-168	.1	7.9	.7	.01	.39
G-169	.1	23.0	.8	0.00	.40
G-170	.1	3.6	1.1	.04	.66
G-171	.1	2.8	1.0	.01	.34
G-172	.1	6.6	.8	0.00	.36
G-173	.1	10.0	.9	.01	.44
G-174	.1	14.0	.9	0.00	.27
G-175	.1	12.0	1.0	.01	.31
G-176	.1	4.7	1.1	.03	.27
G-177	.1	6.4	.9	0.00	.16
G-178	.1	34.0	.7	0.00	.23
G-213	.1	5.3	1.0	.03	.42
G-214	.1	11.0	1.1	0.00	.22
G-215	.1	18.0	.9	0.00	.20
G-216	.1	35.0	1.0	0.00	.26
G-217	.1	32.0	1.2	0.00	.27
G-218	.1	26.0	1.1	0.00	.25

* DTPA Extraction

Table 25
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Soil/Overburden Preplant Analysis pH, Total Phosphorus (P), and Total Potassium (K)

Sample	Soil pH	P/PPM	K/PPM
G-159	7.8	323.2	1461
G-160	8.4	237.9	2238
G-161	8.3	320.0	1230
G-162	8.3	292.8	2369
G-163	8.1	323.8	2689
G-164	8.0	275.0	3859
G-165	7.8	353.8	2661
G-166	8.1	338.1	2251
G-167	8.5	310.7	2838
G-168	8.4	315.6	4541
G-169	8.3	292.7	3378
G-170	7.8	393.7	3564
G-171	8.1	245.5	3152
G-172	8.6	237.0	3102
G-173	7.9	1515.0	3345
G-174	7.9	258.6	2161
G-175	8.0	273.9	1442
G-176	7.5	333.0	2935
G-177	8.2	355.3	2036
G-178	8.8	462.5	2296
G-213	7.8	550.4	3504
G-214	8.3	283.5	3591
G-215	9.0	305.4	1145
G-216	8.6	317.6	2157
G-217	8.6	363.0	2300
G-218	8.6	315.6	2580

Table 25
Sheet 2 of 4

Soil/Overburden Preplant Analysis Total Calcium (Ca), Magnesium (Mg), Sodium (Na), and Zinc (Zn)

Sample	Ca/PPM	Mg/PPM	Na/PPM	Zn/PPM
G-159	8845	11060	106.8	32.33
G-160	8837	11000	172.5	29.41
G-161	8835	10930	186.8	27.00
G-162	8837	10940	291.5	28.90
G-163	8833	10910	312.4	33.34
G-164	8805	10960	428.9	50.21
G-165	6808	5183	174.0	43.69
G-166	8864	11050	206.2	35.42
G-167	8890	11000	299.3	41.21
G-168	8917	11010	460.6	53.63
G-169	8824	10950	377.6	40.87
G-170	9044	7134	245.6	56.85
G-171	8911	11060	259.0	54.20
G-172	8909	10990	366.2	53.93
G-173	8871	10990	658.2	51.97
G-174	8899	10990	379.2	36.00
G-175	8903	10960	494.4	32.78
G-176	6805	4309	206.4	42.53
G-177	8832	11040	206.6	30.30
G-178	8899	10990	424.7	36.75
G-213	8937	11070	195.5	50.49
G-214	8744	10960	751.0	39.84
G-215	8832	10920	1139.0	33.95
G-216	8809	10910	1407.0	36.48
G-217	8797	10900	1602.0	40.44
G-218	8824	10920	1422.0	36.00

Table 25
Sheet 3 of 4

Soil/Overburden Preplant Analysis Total Boron (B), Manganese (Mn), Iron (Fe), and Copper (Cu)

Sample	B/PPM	Mn/PPM	Fe/PPM	Cu/PPM
G-159	6.83	296.7	9007	9.14
G-160	9.44	328.7	9009	7.92
G-161	5.00	248.7	8341	8.71
G-162	6.75	265.3	8972	9.31
G-163	7.59	295.1	8980	9.64
G-164	8.12	365.5	9005	20.83
G-165	8.14	378.8	8989	7.14
G-166	7.16	258.4	9011	7.49
G-167	7.55	271.9	9000	8.91
G-168	10.31	310.2	8992	12.70
G-169	11.06	307.5	8995	10.95
G-170	9.45	450.5	9000	10.17
G-171	8.42	282.6	8992	11.86
G-172	8.06	274.4	8990	11.97
G-173	8.59	263.0	8986	13.14
G-174	6.76	262.6	9008	8.09
G-175	5.48	302.2	8820	6.65
G-176	8.55	350.9	8998	7.43
G-177	8.14	254.6	8996	5.85
G-178	10.32	308.9	8992	7.72
G-213	10.03	372.5	8986	10.80
G-214	10.80	236.8	9006	8.95
G-215	5.18	257.7	8433	8.49
G-216	6.43	267.1	8942	9.02
G-217	9.87	296.7	9003	9.85
G-218	7.67	298.0	9004	7.90

Soil/Overburden Preplant Analysis
Total Cadmium (Cd), Aluminum (Al), Arsenic (As), Molybdenum (Mo), and Lead (Pb)

Sample	Cd/PPM	Al/PPM	As/PPM	Mo/PPM	Pb/PPM
G-159	.22	7713	22.61	0	0
G-160	.16	9455	23.66	0	0
G-161	.08	7535	14.44	0	0
G-162	.12	9582	19.49	0	0
G-163	.01	10360	19.35	0	0
G-164	.24	12590	25.37	0	0
G-165	.22	11800	29.81	0	0
G-166	.18	10990	23.46	0	0
G-167	.19	11620	24.09	0	0
G-168	.27	16880	26.10	0	0
G-169	.22	12650	25.96	0	0
G-170	.31	14640	36.25	0	0
G-171	.33	15800	36.99	0	0
G-172	.33	14300	33.54	0	0
G-173	.18	15080	29.73	0	0
G-174	.15	10420	23.86	0	0
G-175	.20	7760	18.33	0	0
G-176	.15	13010	29.98	0	0
G-177	.12	10870	21.85	0	0
G-178	.13	11740	24.50	0	0
G-213	.28	15200	31.50	0	0
G-214	.26	14710	26.42	0	0
G-215	.31	6955	16.50	0	0
G-216	.20	10240	20.39	0	0
G-217	.30	10890	21.42	0	0
G-218	.26	10530	21.09	0	0

Table 26

Normal Ranges of Selected Elements in Soils*

Element	General Concentration in Soils (in ppm, except Iron)
Arsenic (As)	5-13
Boron (B)	20-700
Cadmium (Cd)	1-10
Copper (Cu)	1-300
Iron (Fe)	0.15-10%
Lead (Pb)	2.6-25
Manganese (Mn)	2-20,000
Molybdenum (Mo)	3-8
Nickel (Ni)	3-300
Selenium (Se)	.001-3.4
Zinc (Zn)	10-2,000

* From: E&A Environmental Consultants, 1982, Heavy Metal Effects on Plant Growth as Related to Animal Nutrition.

Table 27

Statistical Analysis - Soil/Overburden Preplant Analysis
Miscellaneous Data*

Analysis	Mean	Range	Standard Deviation	Coefficient of Variation
Sand (%)	15.5	0.7-37	11.1	0.72
Silt (%)	64.3	45.4-91.3	11.4	0.18
Clay (%)	20.2	8-35.2	7.5	0.37
Saturation percent	41.3	33.1-50.1	5.1	0.12
ECe @ 25°C (mmhos/cm)	5.2	0.4-22	6.0	1.15
Exchangeable Sodium Percentage	6.37	0-26.7	7.7	1.21
Cation Exchange Capacity (me/100g)	11.7	5.3-18.5	3.5	0.30
Ca^{+2} (me/1)	10.0	0.8-33.5	10.1	1.01
Mg^{+2} (me/1)	30.0	1.3-103.5	32.6	1.09
SAR (me/1)	5.4	0.1-21.4	6.4	1.19

* Data supplied by Bureau of Reclamation.

Table 28

Statistical Analyses - Soil/Overburden Preplant Analysis
Plant-Available Levels*

Analysis	Mean	Ranges	Standard Deviation	Coefficient of Variation
pH	8.20	7.50 - 9.00	.35	0.04
P (ppm)	0.30	0.00 - 6.00	1.17	3.90
K (ppm)	46.50	21.00 - 135.00	20.01	0.62
Zn (ppm)	0.25	0.10 - 1.10	0.26	1.04
Cu (ppm)	0.10	0.10 - 0.10	-	-
Fe (pm)	1.57	0.10 - 7.40	2.05	1.31
Mn (ppm)	18.00	2.80 - 61.00	15.74	0.87
DTPA Ni (ppm)	0.93	0.70 - 1.20	0.15	0.16
DTPA Cd (ppm)	0.00	0.00 - 0.04	-	-
DTPA Pb (ppm)	0.33	0.13 - 0.91	.15	0.45

* Data supplied by E&A Environmental Consultants, Inc.

Table 29

Statistical Analyses - Soil/Overburden Preplant Analysis
Total Levels*

Analysis	Mean	Ranges	Standard Deviation	Coefficient of Variation
P (ppm)	365.00	237.00 - 1515.00	238.92	0.65
K (ppm)	2647.00	1145.00 - 4541.00	826.23	0.31
Ca (ppm)	8704.00	6805.00 - 9044.00	550.77	0.06
Mg (ppm)	11840.00	5183.00 - 43009.00	6370.28	0.54
Zn (ppm)	40.33	27.00 - 56.85	8.79	0.21
B (ppm)	8.18	5.18 - 11.06	1.60	0.20
Mn (ppm)	304.10	236.80 - 450.50	48.99	0.16
Mo (ppm)	0.00	0.00 - 0.00	0.00	0.00
Ca (ppm)	0.64	5.85 - 20.83	1.88	0.30
Cd (ppm)	0.21	0.01 - 0.33	0.08	0.38
Pb (ppm)	0.00	0.00 - 0.00	0.00	0.00
As (ppm)	24.85	14.41 - 36.99	5.60	0.23
Fe (ppm)	89.40	8345.00 - 9011.00	164.36	0.02

* Data supplied by E&A Environmental Consultants, Inc.

Table 30
Sheet 1 of 2

Soil/Overburden Postharvest Analysis
Plant-Available Phosphorus (P), Potassium (K), Zinc (Zn), and Iron (Fe)

Sample	P/PPM	K/PPM	Zn/PPM	Fe/PPM
G-159	6	119	2.5	3.9
G-160	3	109	2.1	3.3
G-161	2	91	1.8	4.4
G-162	0	80	1.6	4.3
G-163	0	90	1.6	4.2
G-164	-	86	1.6	4.0
G-165	14	116	.2	.3
G-166	0	71	.1	.3
G-167	6	104	.3	.3
G-168	6	80	.2	.6
G-169	0	99	.2	.6
G-170	15	201	.1	.4
G-171	0	116	.2	.4
G-172	0	83	.1	.4
G-173	0	84	.3	.4
G-174	0	102	.1	.6
G-175	2	86	.4	.8
G-176	22	176	.4	.5
G-177	0	97	.2	.4
G-178	9	116	.1	.9
G-213	7	110	.1	.5
G-214	0	122	.1	.5
G-215	0	86	.1	.6
G-216	0	89	.3	1.0
G-217	0	99	.2	1.5
G-218	0	81	.2	1.0

Soil/Overburden Postharvest Analysis
Plant-Available Copper (Cu), Manganese (Mn), Nickel (Ni), Cadmium (Cd), and Lead (Pb)

Sample	Cu/PPM	Mn/PPM	Ni/PPM*	Cd/PPM*	Pb/PPM*
G-159	1.0	30.00	.6	.02	.35
G-160	.8	27.00	.5	0.00	.19
G-161	.6	32.00	.3	0.00	.32
G-162	.6	36.00	.3	0.00	.31
G-163	.6	38.00	.6	0.00	.59
G-164	.7	45.00	1.1	.01	1.30
G-165	.1	5.40	.6	0.00	.32
G-166	.1	4.90	.4	0.00	.22
G-167	.1	7.90	.5	0.00	.50
G-168	.1	11.00	.7	.01	.70
G-169	.1	29.00	.7	0.00	.51
G-170	.1	5.00	1.1	0.00	.55
G-171	.2	4.10	1.0	0.00	.27
G-172	.2	8.00	.5	0.00	.34
G-173	.1	14.00	.6	0.00	.53
G-174	.1	20.00	1.0	0.00	.55
G-175	.2	18.00	1.1	0.00	.61
G-176	.1	7.20	1.5	.05	.54
G-177	.1	6.50	.8	.01	.22
G-178	.1	34.00			
G-213	.1	6.90	.9	0.00	.38
G-214	.1	14.00	1.1	.02	.36
G-215	.1	25.00	.8	0.00	.26
G-216	.1	44.00	1.0	.01	.56
G-217	.1	39.00	1.3	0.00	.37
G-218	.1	37.00	1.6	0.00	.39

* DTPA Extraction

Table 31
Sheet 1 of 3

Soil/Overburden Postharvest Analysis
Total Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), and Zinc (Zn)

Sample	P/PPM	K/PPM	Ca/PPM	Mg/PPM	Zn/PPM
G-159	625.1	3917.0	13270	2242	77.6
G-160	235.8	2353.0	13170	5798	57.5
G-161	660.7	4380.0	9156	2081	79.8
G-162	377.5	3071.0	2420	2286	76.4
G-163	0.0	3726.0	13230	5286	84.3
G-164	279.8	4098.0	13270	5595	110.3
G-165	352.3	3686.0	13210	6956	86.1
G-166	337.8	3637.0	13140	5905	131.9
G-167	335.7	1149.0	13160	5708	46.6
G-168	347.6	2355.0	13320	7111	120.2
G-169	357.6	3575.0	4157	3242	253.2
G-170	433.7	3300.0	8934	6407	62.0
G-171	270.2	276.5	2307	11010	56.4
G-172	140.8	1289.0	19430	8200	33.0
G-173	270.7	3165.0	23090	14390	52.1
G-174	275.3	2794.0	23160	16300	44.7
G-175	383.9	3151.0	22760	24850	56.1
G-176	434.3	2925.0	7767	4268	47.0
G-177	345.0	1992.0	22980	11810	35.9
G-178	457.7	2346.0	23040	13280	63.9
G-213	541.5	2787.0	23120	9786	58.4
G-214	270.4	3309.0	23000	17730	207.8
G-215	282.2	2707.0	22930	20360	518.4
G-216	330.7	2740.0	22930	20740	43.0
G-217	337.9	2742.0	22960	19860	42.5
G-218	304.6	2863.0	23060	17750	41.6

Soil/Overburden Postharvest Analysis
Total Boron (B), Manganese (Mn), Molybdenum (Mo), Copper (Cu), and Iron (Fe)

Sample	B/PPM	Mn/PPM	Mo/PPM	Cu/PPM	Fe/PPM
G-159	7.2	293.9	0	14.88	10000
G-160	2.7	138.8	0	15.32	5270
G-161	6.8	328.9	0	18.62	10000
G-162	9.2	449.0	0	12.34	10000
G-163	7.9	381.1	0	14.98	10000
G-164	9.6	350.1	0	23.25	10000
G-165	5.0	356.2	0	15.50	10000
G-166	10.6	819.3	0	12.03	10000
G-167	3.6	139.6	0	2.86	7334
G-168	3.7	240.9	0	12.06	8738
G-169	6.3	597.6	0	10.28	10000
G-170	16.4	411.1	0	9.65	10000
G-171	14.7	253.0	0	10.98	10000
G-172	8.5	134.9	0	6.76	7086
G-173	15.8	246.6	0	9.90	10000
G-174	15.2	298.8	0	8.92	10000
G-175	17.6	427.0	0	11.02	10000
G-176	16.1	330.2	0	6.34	10000
G-177	13.8	222.9	0	5.07	9639
G-178	16.4	269.0	0	6.04	10000
G-213	16.7	339.3	0	10.05	10000
G-214	15.9	209.0	0	8.68	10000
G-215	14.0	251.2	0	8.38	9917
G-216	13.7	259.4	0	7.54	10000
G-217	14.2	287.1	0	7.80	10000
G-218	15.1	281.2	0	8.17	10000

Table 31
Sheet 3 of 3

Soil/Overburden Postharvest Analysis
Total Cadmium (Cd), Lead (Pb), and Arsenic (As)

Sample	Cd/PPM	Pb/PPM	As/PPM
G-159	.41	0	0.00
G-160	.45	0	0.00
G-161	.45	0	0.00
G-162	.45	0	0.00
G-163	.49	0	0.00
G-164	.61	0	0.00
G-165	.50	0	0.00
G-166	.62	0	0.00
G-167	.10	0	0.00
G-168	.34	0	0.00
G-169	.58	0	0.00
G-170	.37	0	0.00
G-171	.47	0	30.86
G-172	.45	0	29.86
G-173	.41	0	21.41
G-174	1.68	0	31.76
G-175	.35	0	31.47
G-176	.24	0	27.31
G-177	.25	0	18.94
G-178	.29	0	19.74
G-213	.44	0	27.44
G-214	.41	0	22.34
G-215	.25	0	20.84
G-216	.46	0	21.06
G-217	.30	0	21.52
G-218	.49	0	20.86

Table 32

Statistical Analyses - Soil/Overburden Postharvest Analysis
Plant - Available Levels*

Analysis	Mean	Range	Standard Deviation	Coefficient of Variation
pH	8.50	8.1 - 9.10	0.26	0.03
CEC	26.70	20.6 - 37.70	4.25	0.16
P (ppm)	3.50	0.00 - 22.00	5.67	1.62
K (ppm)	103.60	71.00 - 201.00	28.36	0.27
Zn (ppm)	0.58	0.10 - 2.50	0.73	1.25
Cu (ppm)	0.25	0.10 - 1.00	0.26	1.04
Fe (ppm)	1.39	0.30 - 4.40	1.47	1.06
Mn (ppm)	21.11	4.10 - 45.00	13.70	0.65
DTPA Ni (ppm)	0.79	0.00 - 1.60	0.37	0.47
DTPA Cd (ppm)	0.00	0.00 - 0.05	0.01	--
DTPA Pb (ppm)	0.42	0.00 - 1.30	0.25	0.50

* Data supplied by E&A Environmental Consultants, Inc.

Table 33

Statistical Analyses - Soil/Overburden Postharvest Analysis Total Levels*

Analysis	Mean	Range	Standard Deviation	Coefficient of Variation
P (ppm)	343.49	140.80 - 660.70	113.62	0.32
K (ppm)	2954.70	1149.00 - 4380.00	756.72	0.26
Ca (ppm)	15884.00	2307.00 - 23160.00	7042.39	0.44
Mg (ppm)	10344.00	2081.00 - 24850.00	6564.41	0.63
Zn (ppm)	91.79	33.02 - 518.40	96.07	1.05
B (ppm)	11.42	2.72 - 17.56	4.70	0.41
Mn (ppm)	330.54	134.90 - 819.30	146.40	0.44
Mo (ppm)	0.00	0.00 - 0.00	0.00	0.00
Cu (ppm)	10.67	2.86 - 23.25	4.37	0.41
Cd (ppm)	0.46	0.10 - 1.68	0.27	0.59
Pb (ppm)	0.00	0.00 - 0.00	0.00	0.00
As (ppm)	13.29	0.00 - 31.76	12.76	0.96
Fe (ppm)	9538.00	5270.00 - 10000.00	1146.00	0.12

* Data supplied by E&A Environmental Consultants, Inc.

Correlation Coefficients of Miscellaneous Soil/Overburden Preplant Analyses* Versus Dry Weight of Plants

Dry Weight Vs.	Correlation Coefficient
Sand (%)	.011
Silt (%)	.108
Clay (%)	-.180
Saturation (%)	-.027
EC_e @ 25°C (mmhos)/cm	-.270
Exchangeable Sodium (%)	-.334
Cation Exchange Capacity (me/100g)	.058
Sat. Extract Ca (me/l)	-.250
Sat. Extract Mg (meq/l)	-.263
SAR	-.334

* Data supplied by Bureau of Reclamation

Table 35

Correlation of Dry Weight of Plants Versus Soil/Overburden Preplant and Postharvest Available Levels*

Dry Weight Vs.	Preplant Available	Postharvest Available
pH	-.270	-.099
CEC	-.375	-.444
P	.193	.138
K	.269	.216
Zn	.055	.292
Cu	--	.211
Fe	.099	.270
Mn	-.128	-.460
DTPA Ni	-.269	-.079
DTPA CD	.235	-.105
DTPA Pb	.133	-.070

* Data supplied by E&A Environmental Consultants, Inc.

Correlation of Dry Weight of Plants Versus Soil/Overburden Preplant and Postharvest Total Levels*

Dry Weight Vs.	Preplant Total	Postharvest Total
pH	.143	.159
K	.174	.228
Ca	.019	-.369
Mg	-.052	-.278
Zn	.018	.035
B	.336	-.133
Mn	.217	.095
Mo	0.000	0.000
Cu	-.025	.299
Cd	-.093	.042
Pb	0.000	0.000
As	.171	-.207

* Data supplied by E&A Environmental Consultants, Inc.

Table 37
Sheet 1 of 3

Plant Tissue Data

Sample	P/%	K/%	Ca/%	Mg/%	As/PPM
G-159	.31	2.87	.74	.27	.66
G-160	.31	2.04	.59	.57	0.00
G-161	.73	3.46	.29	.51	4.35
G-162	.52	3.00	.26	.44	0.00
G-163	.34	2.06	.32	.47	0.00
G-164	.58	2.79	.39	.62	3.90
G-165	.39	2.20	.47	.67	2.85
G-166	.40	2.82	1.21	.34	0.00
G-167	.29	1.76	.47	.86	.42
G-168	.50	2.42	.35	.94	2.90
G-169	.37	2.04	.44	.99	2.11
G-170	.26	2.56	.92	.28	0.00
G-171	.21	1.22	1.20	.83	1.37
G-172	.27	1.77	.57	1.09	1.24
G-173	.35	2.44	.71	.65	3.25
G-174	.35	2.88	.89	.74	1.71
G-175	.31	2.43	.64	.54	3.04
G-176	.28	2.80	.81	.21	.90
G-177	.26	1.90	.72	.47	.38
G-178	.31	1.41	.33	.90	4.46
G-213	.39	3.66	.65	.24	0.00
G-214	.34	2.12	.30	.55	0.0
G-215	.34	1.73	.15	.42	.68
G-216	.39	1.70	.19	.41	1.75
G-217	.40	1.99	.43	.63	0.00
G-218	.44	1.96	.41	.58	2.18

Table 37
Sheet 2 of 3

Plant Tissue Analysis

Sample	Cd/PPM	Pb/PPM	Zn/PPM	B/PPM	Mn/PPM
G-159	.49	0.00	35.58	11.70	34.63
G-160	.86	1.49	42.60	16.76	39.97
G-161	.20	0.00	39.71	12.71	48.12
G-162	.48	1.15	37.07	9.29	48.75
G-163	.45	.40	30.46	9.39	62.05
G-164	.35	0.00	51.50	11.33	64.50
G-165	.53	0.00	36.84	10.10	82.75
G-166	0.00	0.00	38.67	14.26	42.50
G-167	0.00	0.00	33.55	24.69	27.60
G-168	.37	0.00	40.8	24.69	31.57
G-169	.46	0.00	237.15	23.76	53.20
G-170	.61	1.32	25.49	9.74	41.05
G-171	.05	0.00	41.37	12.11	29.65
G-172	.33	0.00	28.64	22.58	31.15
G-173	.14	0.00	38.58	26.89	49.52
G-174	.02	39.58	39.58	24.62	51.85
G-175	.12	0.00	40.27	22.03	79.75
G-176	0.00	2.23	30.67	6.87	27.85
G-177	.07	0.00	41.93	12.93	24.92
G-178	0.00	0.00	30.72	46.69	38.67
G-213	.27	3.63	28.02	11.11	41.74
G-214	0.00	0.00	30.34	12.29	32.07
G-215	0.00	0.00	27.99	13.61	46.32
G-216	.31	0.00	29.72	13.88	47.39
G-217	.64	0.00	36.29	15.00	67.85
G-218	0.00	0.00	40.30	25.65	73.70

Table 37
Sheet 3 of 3

Plant Tissue Analysis (and Dry Weight)

Sample	Fe/PPM	Cu/PPM	Mo/PPM	DRY WT/Grams
G-159	121.80	8.33	.60	2.35
G-160	172.60	6.50	0.00	4.32
G-161	107.45	15.77	2.78	2.31
G-162	221.60	14.39	2.48	3.04
G-163	198.65	8.52	2.98	2.61
G-164	212.00	11.67	2.28	1.21
G-165	119.70	9.85	1.49	2.34
G-166	249.15	7.38	1.09	.96
G-167	197.55	8.65	0.00	.48
G-168	435.55	15.15	.40	3.12
G-169	543.00	11.45	3.67	3.41
G-170	201.65	5.25	.55	3.06
G-171	332.90	4.86	0.00	2.92
G-172	576.00	10.38	2.09	.92
G-173	196.90	9.49	2.55	2.87
G-174	139.05	12.20	2.73	1.98
G-175	225.50	12.07	2.64	2.19
G-176	85.30	5.91	.64	2.09
G-177	260.85	10.10	.64	2.01
G-178	502.00	6.48	2.46	1.90
G-213	98.30	5.86	1.19	3.04
G-214	113.80	6.22	.73	1.78
G-215	134.95	6.09	3.19	1.83
G-216	194.90	8.99	2.64	1.01
G-217	113.00	9.31	3.19	1.35
G-218	206.1	10.11	3.47	2.21

Table 38

Statistical Analyses - Plant Dry Weight and Tissue Analysis

Analysis	Mean	Ranges	Standard Deviation	Coefficient of Variation
Dry Wt. (grams)	2.20	0.48 - 4.32	0.87	0.40
P (%)	0.37	0.21 - 0.73	0.11	0.30
K (%)	2.31	1.22 - 3.66	0.59	0.26
Ca (%)	0.56	0.15 - 1.21	0.28	0.50
Mg (%)	0.59	0.21 - 1.09	0.24	0.41
As (ppm)	1.47	0.00 - 4.46	1.45	0.99
Cd (ppm)	0.26	0.00 - .86	0.24	0.92
Pb (ppm)	1.92	0.00 - 39.58	7.58	3.95
Zn (ppm)	43.61	25.49 - 237.15	39.16	0.90
B (ppm)	17.10	6.87 - 46.69	8.46	0.49
Mn (ppm)	46.89	24.92 - 82.72	16.06	0.34
Fe (ppm)	229.24	85.30 - 576.00	135.44	0.59
Cu (ppm)	9.27	4.86 - 15.77	2.99	0.32
Mo (ppm)	1.79	0.00 - 3.67	1.18	0.66

Correlation Between Dry Weight of Plants and Plant Tissue Analysis

Dry Weight Vs.	Correlation Coefficient
P	--
K	.187
Ca	.061
Mg	-.080
As	-.036
Cd	.472
Pb	--
Zn	.289
B	-.086
Mn	.018
Cu	--
Mo	-.128

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